PRODUCTION POTENTIAL OF COPPER DEPOSITS ASSOCIATED WITH PERMIAN RED BED FORMATIONS IN TEXAS, OKLAHOMA, AND KANSAS

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

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by

R. B. Stroud,[1] A. B. McMahan,[2] R. K. Stroup,[3] and M. H. Hibpshman[4]

ABSTRACT

Bureau of Mines studies of copper-bearing Permian red beds, which extend from north-central Texas through western Oklahoma to southwestern Kansas, indicate heretofore undefined commercial possibilities for low-grade, medium-volume, strip-mining operations. Potential ore bodies are indicated containing 0.5 to 1.5 percent copper in zones 6 to 12 inches thick. Cost analysis studies indicate a commercial operation is feasible for a hypothecated 1,000-ton-per-day ore mining and milling complex where a maximum of 60 feet of overburden can be stripped in mining a seam of shale 12 inches thick containing 1.2 percent copper.

INTRODUCTION

During 1967-69, the Bartlesville (Okla.) Office of Mineral Resources, Bureau of Mines, investigated selected copper deposits in Texas, Oklahoma, and Kansas to determine their commercial potential. The project objective was to develop information useful to industry and Government concerning deposits of metals that may have commercial production potential and that possibly could assist in alleviating future production deficits. Project activities included reconnaissance of known copper occurrences, drilling for subsurface samples, sampling outcrops that indicated favorable areas for copper deposition, and attendant analyses.

Most of the available reports concerned with copper deposits in the discussed area describe geologic and economic aspects of copper in a cursory manner. However, a recent report concerned with a specific deposit has included more detail and indicates favorable opinion toward economic development of copper deposits in the Permian red bed formations (11).[5]

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[5]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

This report presents an evaluation of copper-bearing strata and includes recommendations for future work, especially mining research. Also an attempt is made to define and narrow the search for additional, and higher grade deposits by presenting factual data concerning some copper occurrences. No definitive tonnages of copper are given because ore reserves were not calculated; however, substantial copper mineralization, some of which is of potential commercial significance, was found over large areas. An economic section is included that describes extraction and processing methods and costs, by assuming size and grade of a potential ore body.

Since the work was performed, but before this report had been published, several companies began exploration for copper in the area covered by this study. The results of subsequent drilling and sampling by private companies, reportedly, have been favorable and considerable investment for exploration has been programed.

ACKNOWLEDGMENTS

The earnest cooperation of owners and tenants for permitting access to lands involved in the drilling program in Texas and to landowners elsewhere in the three-State area who granted admittance to their properties is gratefully appreciated. These people also contributed valuable historical information.

BACKGROUND

The area of interest encompasses about 60,000 square miles; the amount of geologic information available concerning outcropping strata, and oil and gas well-drilling data is imposing, but little information exists about the copper mineralization. Only broad discussion is given the geologic strata of the Permian system that are the host rocks for copper mineralization.

Copper occurrences are found in a sinuous belt of outcropping strata extending southward from Barber and Harper Counties, Kans., to Tom Green County, Tex. Figure 1 shows the general configuration and areal extent of geologic formations that contain copper occurrences known at this time to have potential. Although several copper-bearing beds were examined, the field of interest was largely limited to an area in north-central Texas (fig. 2). Appendix A summarizes pertinent data concerning principal deposits examined.

Areal studies were limited by the time allocated. Medicine Mounds, Truscott, and Buzzard Peak, designated 1, 2, and 3 on figure 2, became the principal target areas.

HISTORY, DEVELOPMENT, AND PRODUCTION OF COPPER

The presence of copper in Permian red bed strata in what is now Texas and Oklahoma was first reported by Captain R. B. Marcy in 1852 (17), although its existence was known much earlier to the Spaniards, Mexicans, and Indians. Early development of these low-grade, thin, relatively unexplored copper deposits was hampered by the lack of economic mining and milling techniques.

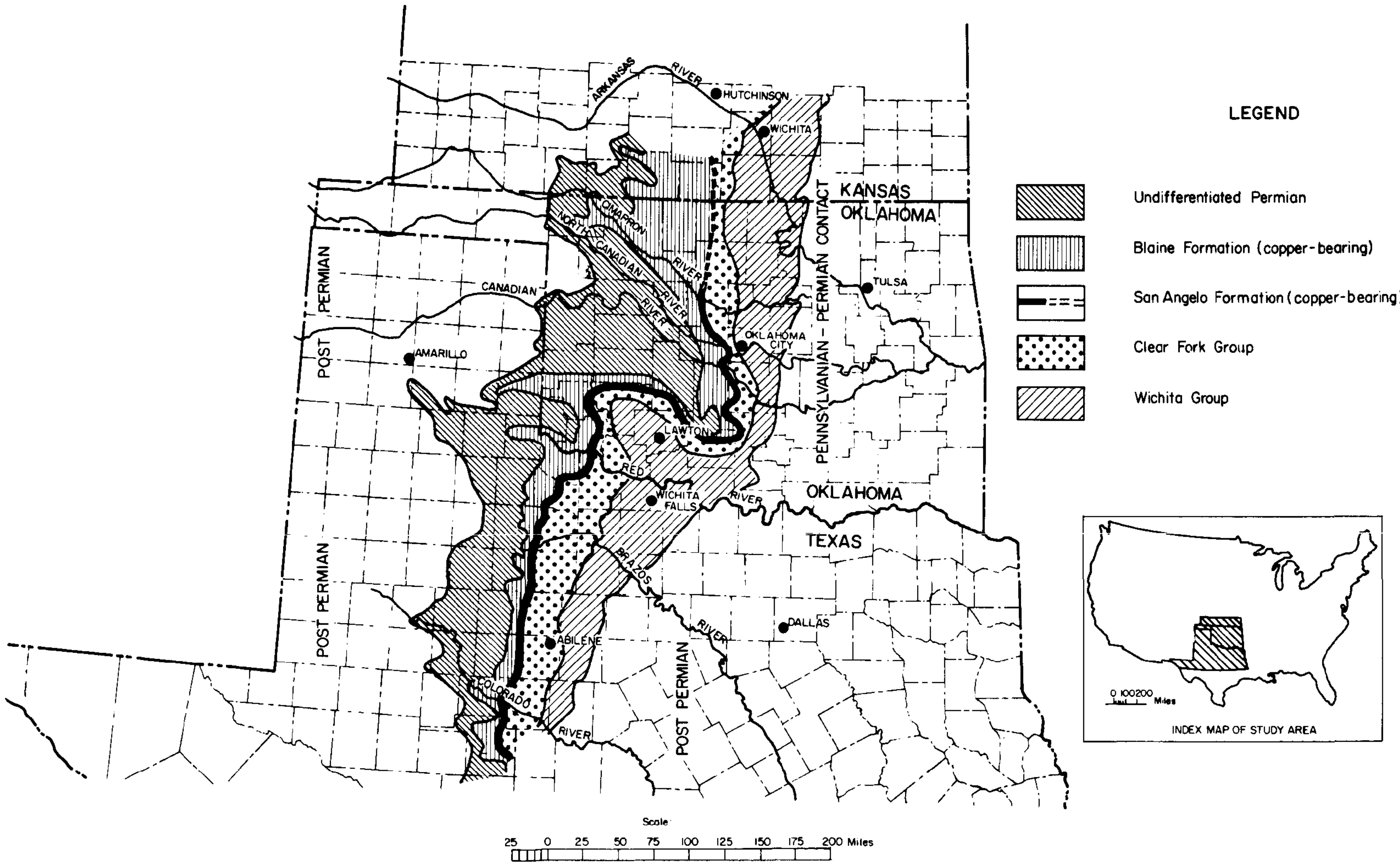

FIGURE 1. - Areal Extent (Copper-Bearing) Permian Formations–Texas, Oklahoma, and Kansas.

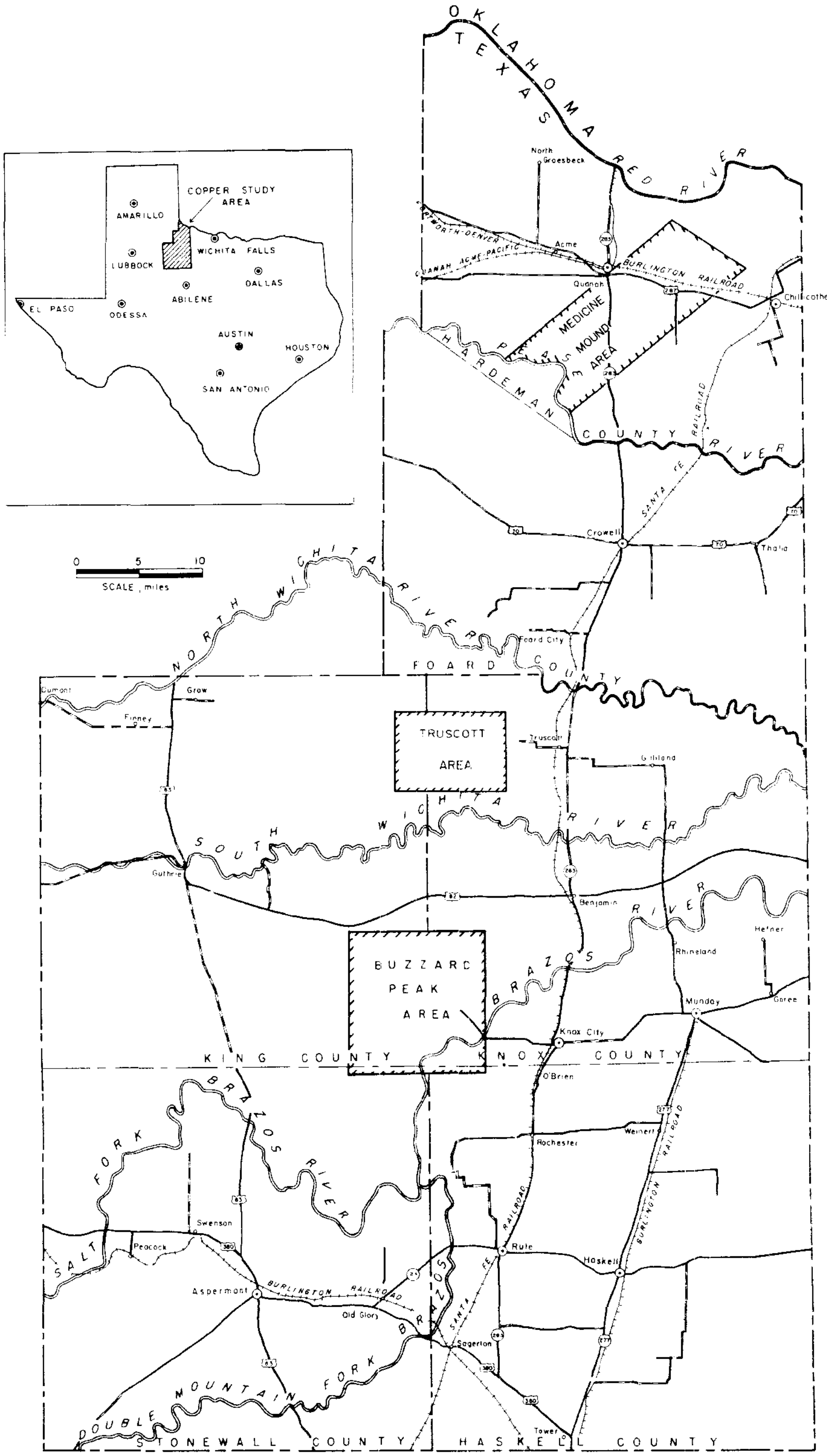

FIGURE 2. - Location Map–Copper-Bearing Areas in Texas Examined by Detailed Reconnaissance and Drilling Operations.

Recent developments in the copper market and advancements in mineral dressing and mining technology, however, have changed the future outlook for copper production from Permian red bed deposits, and currently, annual production exceeds total production for the period 1864-1965. At the time this report was prepared Eagle-Picher Industries, Inc., was stripping up to 40 feet of overburden and mining a thin deposit covering a large area in Jackson County, Okla., and four other mining companies were active in exploration and development in north-central Texas and southwestern Oklahoma.

Processing of Permian copper ores prior to 1965 consisted of gravity separation and hand cobbing; also, some mine-run ore was shipped directly to the smelter (5). In the milling processes, the ores were crushed by rolls or in a mill having vertical rollers running in a circular enclosure with a stone or iron base or die. The copper minerals were separated from gangue material in wooden jigs. At some sites, leaching tanks and vertical furnaces were erected (2, 5).

Analyses of samples of ore and mill tails taken at abandoned mill sites indicate a very low recovery of the copper. With improved equipment and flotation techniques, Eagle-Picher Industries, Inc., has been profitably milling copper-bearing Permian red bed shales in a 1,000-ton-per-day plant in Jackson County, Okla.

STRATIGRAPHIC AND GEOGRAPHIC SETTING

Reports on Permian red bed formations indicate the earliest geological work pertaining to development of stratigraphic nomenclature began in the 1890's. Vertical and horizontal facies changes are frequent in the Permian rock section that has been found to contain copper and these characteristics inhibit correlation of individual beds over extended distances. Indeed, in some places less than a mile apart, correlation is difficult. However, stratigraphic beds can be classified into groups. Copper occurs in rocks of the Wichita, Clear Fork, and Double Mountain (Pease River) Groups in Texas, and in their correlatives in Oklahoma and Kansas (fig. 3).

The formations of interest crop out in parts of an area 530 miles in length and up to 180 miles wide in Texas, Oklahoma, and Kansas (fig. 1). Population of the area, including seven counties in Kansas, 32 counties in Oklahoma, and 25 counties in Texas, was 2,156,061 in 1960. Total land area is 58,713 square miles. Principal cities in or immediately adjacent are Abilene and Wichita Falls, Tex., Lawton, Oklahoma City, Norman, and Enid, Okla., and Wichita, Kans. (fig. 4). The area can be traversed in any direction either by highway or railroad networks.[6] Principal rivers are the Arkansas, Cimarron, North and South Canadian, Washita, Red, Brazos, and Colorado. These rivers and a myriad of tributary streams drain the area to the southeast.

The economy of the area encompassing the copper-bearing formations is based primarily on agriculture and mineral production. Value of mineral production was about $1 billion in 1967 and value of farm production was estimated $673 million (19, 35). Principal minerals produced were petroleum, natural gas, natural gas liquids, sand and gravel, clay and gypsum. Agricultural products include beef cattle, wheat, cotton, barley, grain sorghum, oats, and alfalfa.

Various light industrial and manufacturing operations exist throughout the area. The operations consist mainly of petroleum refining; food processing; textile and apparel manufacturing; stone, clay, glass, gypsum, and concrete products; fabricated metal and machinery products; oilfield equipment; and printing and publishing.

[6]State and county highway maps are available from appropriate State highway departments.

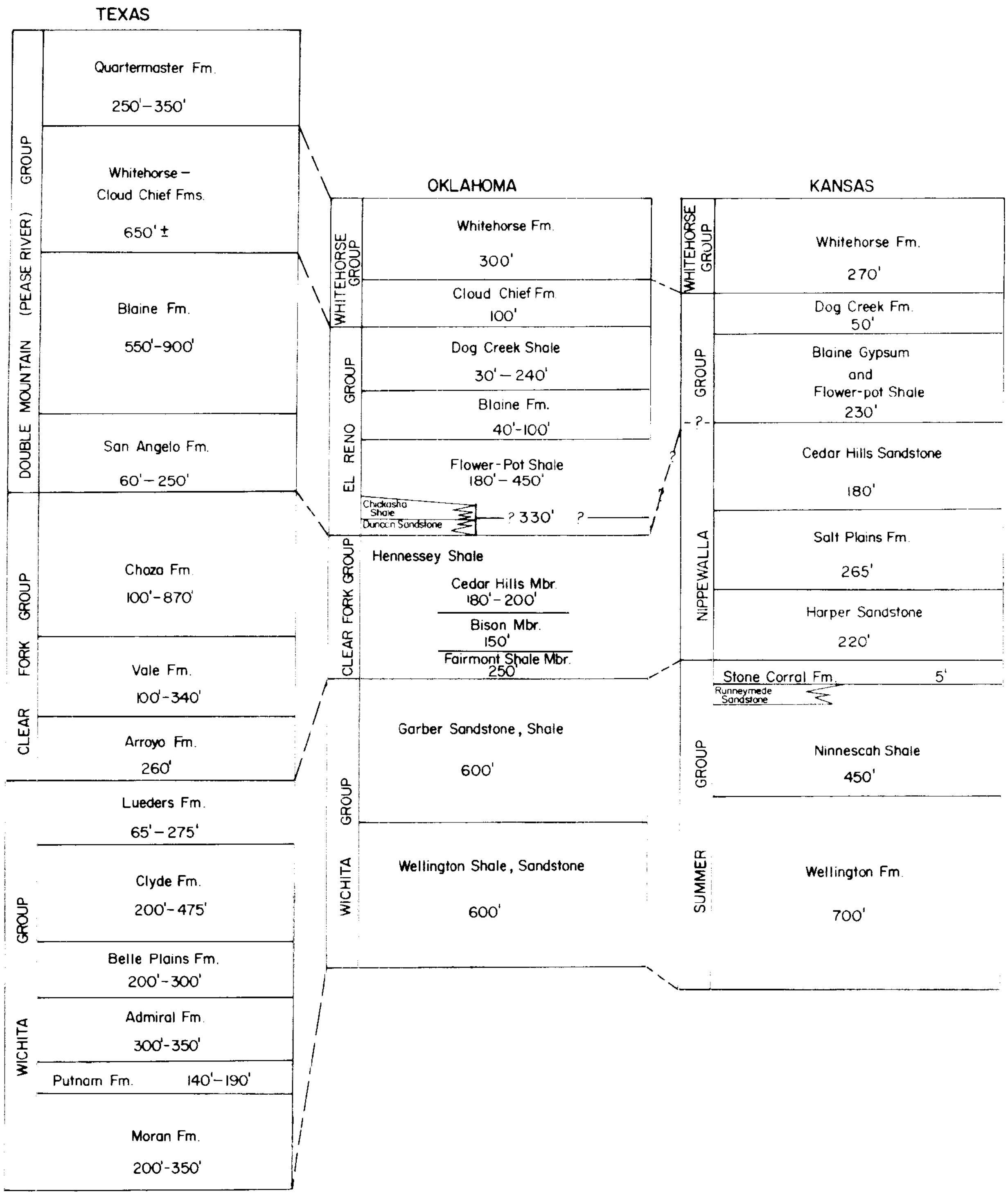

FIGURE 3. - Stratigraphic Chart–Permian Formation Correlations in Texas, Oklahoma, and Kansas.

About 498,000 nonfarm workers were employed in the area in 1967. These included about 124,000 in manufacturing, 151,000 in wholesale and retail trade,

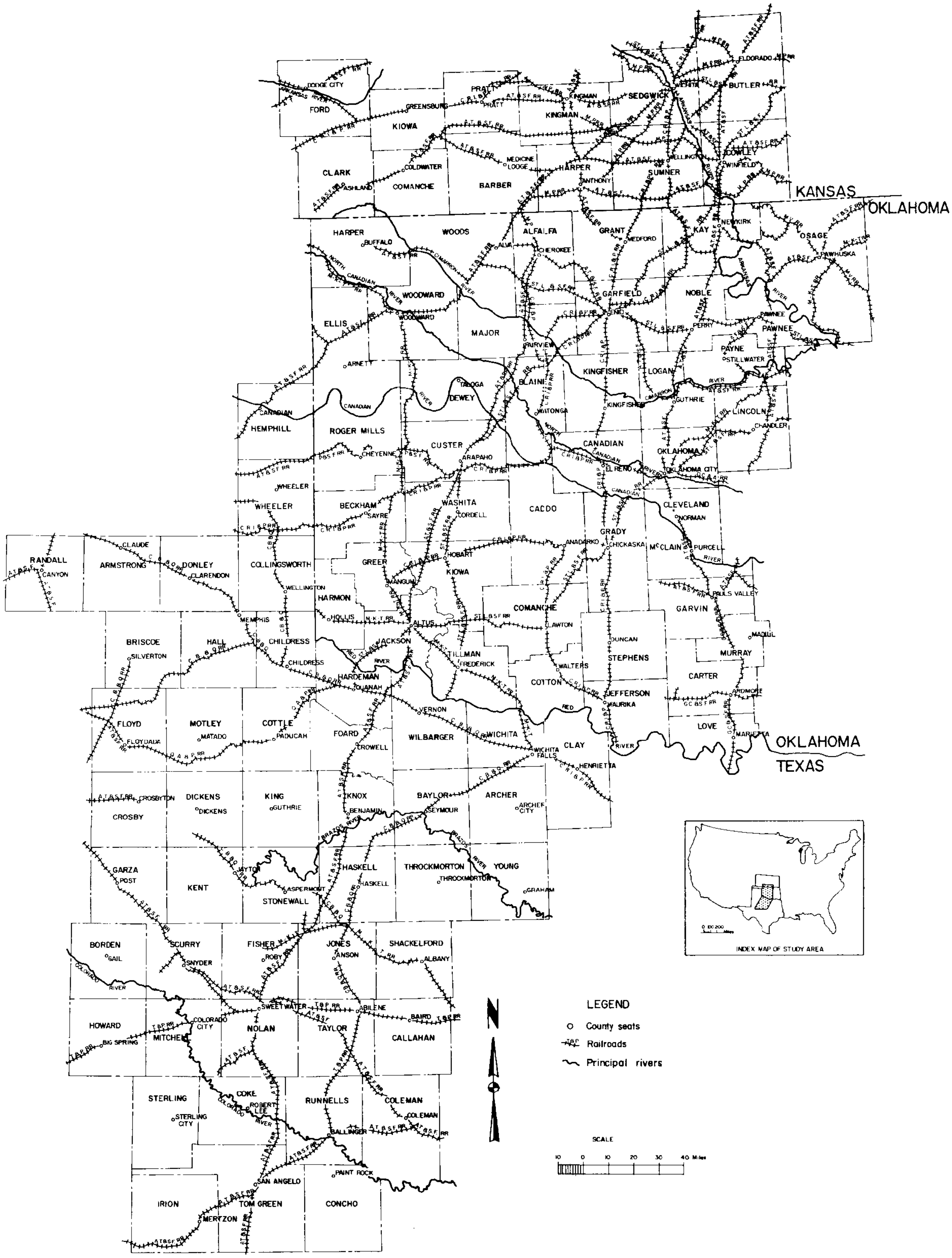

FIGURE 4. - Principal Towns, Railroads, and Streams in Copper-Bearing Area in Texas, Oklahoma, and Kansas.

and about 27,000 in mineral industries (principally petroleum industry); the remaining 196,000 nonfarm workers were employed primarily in services, construction, and transportation (34).

GENERAL GEOLOGY

Physiography

The copper-bearing area discussed in this report encompasses parts of four physiographic areas in Texas (Gypsum Plains, Red Beds, Abilene-Haskel Plains, and Red River Rolling Plains); four in Oklahoma (Rolling Plains, Wichita Mountains, Gypsum Hills, and Enid Prairies); and one in Kansas (Red Hills). Detailed discussions or maps of physiographic areas and relationships are found in several references (10, 16, 25).

Altitude in the Texas physiographic area ranges from about 1,480 to 2,000 feet. Much of the Oklahoma and Kansas area ranges in altitude from about 1,275 to 2,100 feet. Generally, the terrain, with the exception of the Wichita Mountains, is a rolling plain, broken intermittently with escarpments with low relief along principal drainages and their tributaries (fig. 4); small monadnocks occur sporadically and are commonly reference points for location.

The Wichita Mountains extend northwestward from Fort Sill in Comanche County, Okla., about 65 miles into eastern Greer County, Okla. The greatest width, in the central part of the mountain range, is about 30 miles. Elevations of the mountains range from about 1,350 feet to a maximum of about 2,700 feet above sea level. The area adjacent to the mountain range is peneplained and, as a result, the mountains are visible from every direction for several miles.

Stratigraphy

Wichita Group

This group is comprised of the Lueders, Clyde, Belle Plains, Admiral, Putnam, and Moran Formations in Texas (28-29) (fig. 3). Correlatives in Oklahoma are the Garber and Wellington Formations, and in Kansas, the Summer Group, consisting of the Stone Corral Formation, Ninnescah Shale, and Wellington Formation (15, 21). The Wichita Group is about 1,500 to 1,600 feet thick in Texas, approximately 1,200 feet in Oklahoma, and possibly 1,150 feet thick in Kansas. The outcrop pattern of the group forms a north-south belt through a broad area and Wichita rocks apparently overlap Pennsylvanian strata conformably. The rocks consist of interlayered shale, limestone, mixed sandstone and shale, sandstone, and calcareous marls. Red colors predominate, but shades of greens, grays, and brown are notable in some exposures. Possibly the gray and green colorations are the result of alteration by leaching. Copper occurrences in the Wichita Group are described later in this report.

Clear Fork Group

The Clear Fork Group in Texas includes the Choza, Vale, and Arroyo Formations (28). Counterparts in Oklahoma are the Hennessy Shale (Cedar Hills, Bison, and Fairmont Members) and in Kansas the Cedar Hills, Salt Plain, and Harper Formations (classified as part of the Nippewalla Group). In Texas the Clear Fork is 1,200 to 1,500 feet thick, and in Oklahoma and Kansas, respectively, 590 and 665 feet. Shales, limestones, marls, gypsum, dolomites, sandy shales, and sandstones are interbedded and thicknesses of individual beds range from a few inches to several feet. Reds predominate, but gray, green, and brown colors occur frequently. The few known copper occurrences in the Clear Fork are described in a subsequent section.

Double Mountain (Pease River) Group

The Double Mountain or Pease River Group in Texas consists of the Quartermaster, Whitehorse, Cloud Chief, Blaine, and San Angelo Formations (28). The Whitehorse and El Reno Groups in Oklahoma are correlatives of the Double Mountain Group (with exception of the Quartermaster Formation) in Texas. In Oklahoma, the El Reno Group includes the Dog Creek Shale, Blaine Formation, and the Flower-Pot Shale with the Chickasha Shale and Duncan Sandstone Members. The Quartermaster, Whitehorse, and Cloud Chief Formations are assigned to the Whitehorse Group. In Kansas, the Dog Creek Formation, Blaine Gypsum, and Flower-Pot Shale occupy the same stratigraphic interval as the El Reno Group in Oklahoma. The lower part of the Blaine and the San Angelo Formations in Texas are correlative with the Flower-Pot, Chickasha, and Duncan beds in Oklahoma and the Flower-Pot in Kansas, although in the Kansas section little or no sandstone is apparent.

The Blaine and San Angelo Formations have a combined thickness ranging from 610 to 1,150 feet in Texas, from 580 to 1,120 feet in Oklahoma, and 285 feet in Kansas. Changes in thicknesses, mode of deposition, and facies laterally create difficult correlation problems.

Reds and browns predominate in the Double Mountain Group but grays and greens are frequent in a number of places. The variations in color in part are probably the result of the passage of ground waters and are indicative of permeable zones, typify leaching and bleaching characteristics, and indicate changes in type of sediments deposited.

Most of the copper occurrences having commercial potential are found in the Double Mountain (Pease River) Group. They are described in subsequent parts of this report.

Structure

The Wichita Mountains (Wichita Uplift) in Oklahoma and the buried Amarillo Mountains (Amarillo Uplift), and the Anadarko and Palo Duro-Hardeman Basins are the principal tectonic features in the area discussed herein.

The outcropping granitic Wichita Mountains have a northwestern subcrop that apparently centers near the boundary corner common to Moore, Hutchinson, Potter, and Carson Counties, Tex. The resultant structural feature is known as the Amarillo Mountains; although buried by sediments, the granitic rocks have been penetrated in drill holes. Periodic uplift of the Amarillo Mountains occurred throughout much of their development and, in all probability, these eroded mountains and the Wichita Mountains were source rocks for much of the early Permian sediments. The later stages of Permian sedimentation, comprised of a red bed series interspersed with infrequent strata of marine and lagoonal environments, covered the Amarillo Mountains and overlapped portions of the Wichita Mountains. The basin regions, Anadarko and Palo Duro-Hardeman, were principal recipient areas for the clastics and marine deposits.

Periods of upwarp, emergence, and submergence were in part responsible for differentiation in type of sediments deposited and also resulted in formation of gentle regional dips and infrequent faulting that is seemingly characteristic of the Permian sediments in the area discussed in this report. The structural picture is not known in any detail; thus the influence of structure on copper deposition, if any, is not known.

Mode of Occurrence of Copper and Related Features of Host Rocks

Solutions to problems encountered in finding and developing commercial deposits of copper in the Permian red beds are dependent to a large degree on observing and understanding a variety of geological criteria, particularly those relating to the origin of the deposits. Information reported here is largely based on field observations and information gained from subsurface sampling.

These observations suggest to the writers that the copper mineralization was later than deposition of the host rock and was probably the result of moving waters containing copper in solution permeating into strata favorable for deposition. The copper is believed to have been precipitated from solution and deposited along bedding planes, as fracture fillings, pore fillings, in vugs, and as a replacement of other minerals in the host rock. Copper minerals apparently have formed in favorable zones in host rocks which contain (1) saturations of atmospheric waters high in magnesium and calcium, (2) concentrations of carbonized wood and plant material, and (3) sulfur, either in the form of pyrite or other compounds such as gypsum, or host rocks containing hydrogen sulfide. It is believed that there is a high ratio of ferrous to ferric iron thus contributing to a reducing environment. The sedimentary section containing copper includes shale, sandstone, mudstone, siltstone, gypsum, dolomite, and conglomerate; such strata are interbedded and are more or less lenticular. Thicknesses of the beds range from a few inches to several feet. For the most part, a near-shore depositional environment is indicated.

It was observed that three modes of copper occurrences are prevalent; the copper occurrences are directly related to attitude, shape, and extent of host rocks. Copper occurrences are found in three different kinds of rock bodies: those comprising sediments deposited under channel-scour conditions in streams; in fans or deltas; and in lagoons. Lateral extent, grade, and thickness of copper-bearing materials are obviously partly controlled by the geometry of the rock body which contains them.

Channel-scour copper deposits have less areal extent and have a relatively high copper content; this is probably because of the limited physical confines and attitude of host rocks which would tend to permit enrichment through introduction of copper-bearing solutions. Limitations in size may preclude commercial development unless a deposit is favorably situated and grade of contained copper is relatively high.

Copper in alluvial fan or deltaic deposits is found associated with concentrations of fossilized wood and plant material and with some pyrite, dolomite, and infrequently gypsum. Such deposits occur near or at the contact of deltaic sandstone beds with underlying impermeable beds of mudstone or shale. These copper-bearing deposits probably extend over several square miles and, as observed, few exhibit channeling and scouring characteristics. Thicknesses range from a few inches to a foot. Continuity of copper mineralization is sometimes difficult to trace because of the wide variations in thickness and facies changes of the host rocks or because leaching is prevalent along the outcrop. Some of these deposits appear large enough and of high enough grade to be minable.

Rocks comprising sediments thought to have been deposited in a lagoonal environment also contain copper minerals. The principal rocks present are dolomite, gypsum, mudstone, and shale. Carbonaceous material and pyrite is usually present in very finely divided form. Host rock units appear more continuous and more uniform in thickness than in other types of copper deposits. Copper mineralization is likewise more continuous and of a uniform grade, but not necessarily as high in grade as in many channel deposits. Copper-bearing rock bodies are estimated to range in size from several thousand to a few million tons. Volume and attitude of ore bodies are dependent on the size and shape of shallow basins that provided favorable environments for copper mineralization. These copper deposits probably are the most favorable for sustained mining operations of moderate size.

BUREAU OF MINES ACTIVITIES

Reconnaissance Examinations and Preliminary Sampling of Copper Deposits

Field reconnaissance examinations were started following a study of available descriptions of copper occurrences. These data, however, were scant and often incomplete, and locations of copper prospects were poorly described. In past years most, if not all, attempts to mine deposits were financial failures. Very few geologic maps showing location of copper occurrences are available and suitable topographic map coverage is incomplete. The copper-bearing areas are generally remote from highways and railroads.

Acquisition of property ownership maps and topographic maps, many of which were in a preliminary state of completion, proved to be invaluable to field teams in early stages of reconnaissance activities. Preliminary field reconnaissance examinations of Permian formations began in October 1967. At that time, 17 "mines or prospects" were known in Oklahoma through literature research. Twenty-three comparable occurrences were known in Texas. No "mines or prospects" as such were mentioned in the Kansas geological literature. Field examinations were made in 1967 and 1968. Appendix B contains sample analyses data. In addition to copper, spectrographic analyses indicated the presence of silver, vanadium, nickel, lead, gallium, titanium, and zirconium. Such samples usually contained copper oxide minerals in greater abundance than copper sulfides.

Project limitations prevented a complete reconnaissance of the total area of copper-bearing outcrops in parts of Texas, Oklahoma, and Kansas (fig. 1). Therefore, the major effort was expended in three areas in Texas (fig. 2). Several criteria were used in selecting the areas for detailed reconnaissance study and subsequent drilling operations, including results of initial copper analyses of samples; accessibility by means of roads, including county and ranch roads; availability of usable topographic maps; permission of landowners to enter and drill on certain lands; and the type of deposit. Several other comparable areas in the same three-State region containing copper deposits also are worthy of detailed studies to determine the copper production potentialities. For convenience in presentation of information, copper occurrences are described in succceeding sections by beginning in Kansas and extending south into Oklahoma and Texas. In addition, appendixes A and B contain other information about specific deposits.

Kansas

Following development of commercial copper deposits in the Permian red beds in Oklahoma, renewed interest was directed to copper occurrences in the Wellington Formation and the Ninnescah Shale in Kansas in 1966-67 (14). These copper occurrences were noted in geologic reports published in 1939, 1951, and 1955 (22-23, 31). A reconnaissance examination was made of some copper-bearing outcrops in Kansas by Bureau of Mines personnel in 1968. Particularly, samples were taken of dolomitic material from the Milan Dolomite Member (not shown in fig. 3), at the top of the Wellington Formation, and the Runnymede Sandstone Member of the Ninnescah Shale. Analytical results and other data are shown in appendix B (sample sites 104-107). Thin films of malachite occur along clay-filled bedding planes of highly weathered thin-bedded dolomite. The mineralization appears to be superficial; no copper minerals were noted in less weathered material a few inches to a few feet behind the outcrop. Much of the area is of very low relief and a mantle of clayey alluvial sands and gravel precludes lateral tracing of mineralization over extensive areas. The mineralized belt probably extends northward from the southern parts of Harper and Sumner Counties into Kingman and Sedgwick Counties (14).

Oklahoma

Copper deposits in Oklahoma appear to be associated with at least two of the three modes of depositional environment described in foregoing parts of this report. Copper mineralization in some areas is associated with channeling and scouring; other copper is found in basinal (lagoonal) areas which are more extensive. Copper deposits in Oklahoma, associated with the Permian formations, have been noted or described in various reports (3-4; 9; 11-13; 17-18; 20; 32; 36, 1913, p. 159).

In addition to these reports, several county geological reports published by the Oklahoma Geological Survey contain references to copper in Oklahoma. Appendixes A (mines 1-4) and B (sample sites 1-25) contain pertinent data related to some Oklahoma copper deposits.

Fifteen copper occurrences selected from the known occurrences in nine counties were examined. Copper occurrences were noted in a total of 23 western Oklahoma counties; deposits associated with Permian red beds in Garvin, McClain, Jackson, Beckham, and Greer Counties appear to have potential. At the time this report was prepared, commercial production of copper was only in Jackson County.

The better known channel-type deposits are the Teepee Queen prospect and other comparable deposits in Garvin County and the Byars prospect in McClain County. The deposits are typical of the channel-fill type of copper occurrences.

The Teepee Queen deposit is about one mile southeast of Paoli in the SW 1/4 SW 1/4 sec 18, T 4 N, R 1 E. Copper minerals (mostly chalcocite and malachite) are found in a 30-inch-thick zone of the Garber Sandstone. Copper and silver ores have been mined from two or more open cuts approximately 200 to 300 feet in length and 30 to 40 feet wide. Carbonaceous material, barite, and iron minerals are abundant. Sloughing of the side walls of pits prevents determination of the lateral extent of mineralization; however, judging from extent of surface workings, the most highly mineralized zone covers an area of only a few hundred yards. A grab sample of apparently higher grade material contained 8.6 percent copper and 1.6 ounces of silver per ton. No visible copper mineralization was observed in the face of a cut flanking the deposit.

Mineralized occurrences comparable with the Teepee Queen deposit are found in the NE 1/2 NE 1/4 sec 18, and the SW 1/4 sec 7, T 4 N, R 1 E. A close-spaced drilling program would be necessary to trace the deposits in the subsurface.

The Teepee Queen deposit was probably discovered prior to 1900; however, available records indicate that only a few tons of hand-picked ore were shipped a few years prior to World War I (20).

The Byars prospect is about 5 miles southwest of Byars in the SW 1/4 SE 1/4 sec 33, T 5 N, R 2 E. This deposit was worked first shortly before 1900. The deposit was again worked about 1913 when 29 tons of ore were shipped; smelter returns indicated a silver recovery of 1,300 ounces valued at $785 (36, 1913, p. 159). Silver production was 6,187 ounces valued at $3,421 in 1914; 190 tons of copper ore were shipped (36, 1914, pp. 29, 114). The deposit is exposed in shallow open cuts on the west flank of a north-south trending gully. Old workings include shallow-cuts, pitting, and adits all now nearly obliterated by erosion. Sloughing of gully banks prevents tracing of mineralization laterally. Visible ore minerals are mainly malachite and chalcocite in sandstone fragments spread sporadically over the floor of the gully. In addition to copper and silver minerals, barite occurs sparingly in a leached zone in interbedded sandstone and shale of the Garber Sandstone. Analyses of surface samples are not conclusive as to grade of the deposit and a trenching and drilling program would be necessary to determine commercial potentials of the deposit and surrounding area.

Other copper deposits in Oklahoma are associated with basinal environments. Typical among these are the Creta deposits in Jackson County currently being exploited by Eagle-Picher Industries, Inc. (1969) (fig. 5), and the Mangum deposit in Greer County which has been an object of study by the Lobaris Copper Co. since about 1963. The Creta copper deposit has been described by Ham and Johnson (12). The following information was taken largely from that report:

Two persistent copper-bearing horizons are closely associated with the Kiser Dolomite Bed (not shown in fig. 3) of the Flower-Pot Shale. Outcrop samples of the "upper copper" horizon contain 0.38 to 1.27 percent copper,

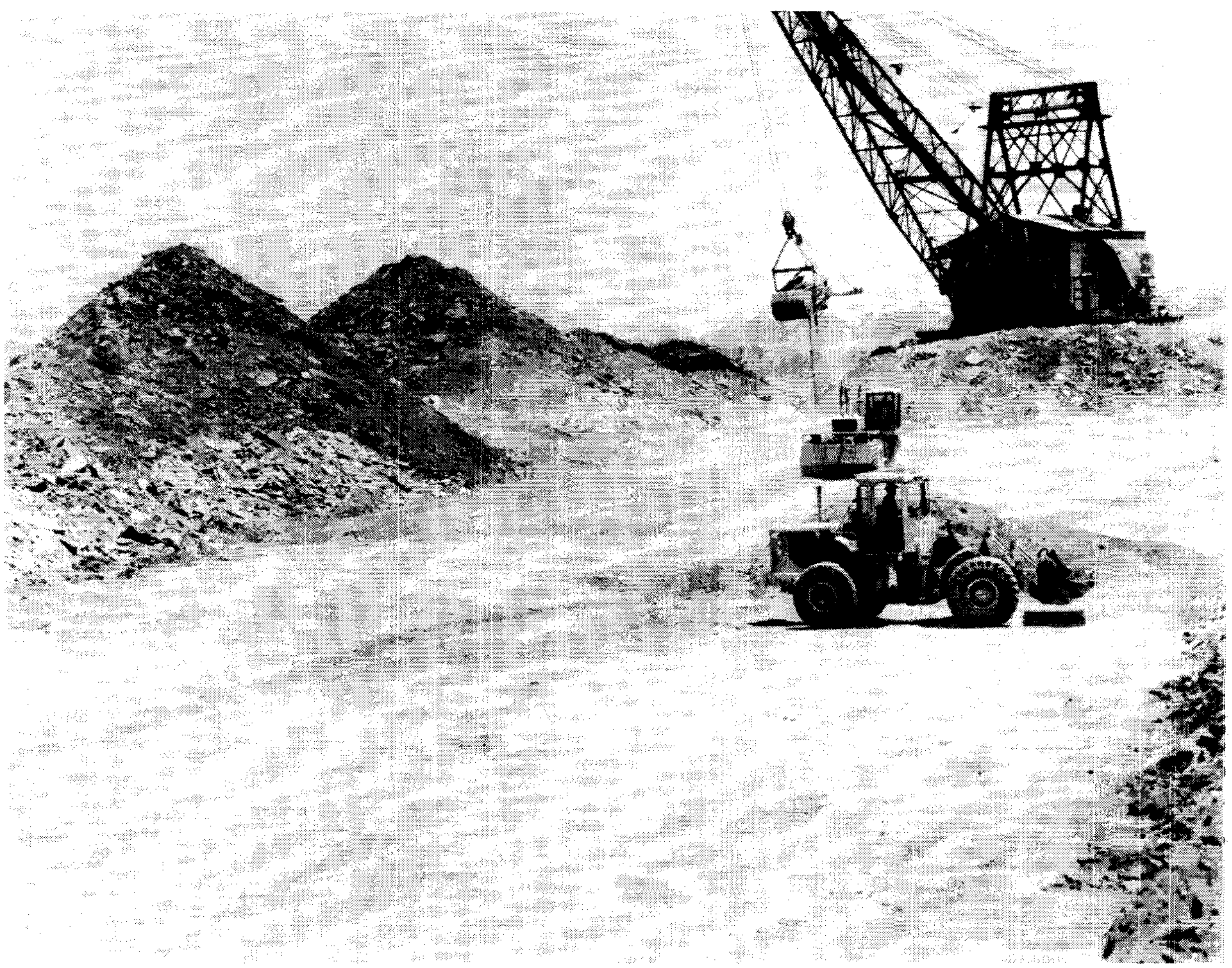

FIGURE 5. - Eagle-Picher Mine Operation.

whereas samples of outcrop of the lower bed contain 2.65 to 4.45 percent copper. Silver content is 1 to 3 ounces per ton of ore. The deposit has been mined by open-cut operations since November 1965. The ore has been beneficiated in a flotation plant and the concentrate shipped to smelters for reduction to metal. Since inception of operations, copper output has been substantial.[7]

The deposit includes, but is not limited to, parts of secs 3, 10, and 15, T 1 S, R 22 W, and is about 5 miles southwest of Olustee, Okla. Only the lower copper-bearing zone has been mined. The average thickness of the ore zone is 6 inches. Ore minerals include both sulfides and carbonates among which are chalcocite and malachite.

The northermost limit of the Mangum copper deposit in sec 10, T 4 N, R 22 W, is about 1.5 miles south of Mangum. From this point, cupriferous outcrops can be found southward for about 8 miles. A comparable copper-bearing zone, however, extends north and westward into Beckham County but has not been explored. Analysis of surface samples from the Mangum deposit are shown in appendix B (sample sites 6-16).

The copper-bearing stratigraphic section exposed at the Mangum deposit is similar to that of the Creta copper area. Probably, the copper mineralization at Mangum is slightly higher in the stratigraphic section than at the Creta deposit. Part of the deposit was (1969) controlled by Lobaris Copper Co. which has conducted exploration and metallurgical testing. Work on the copper deposits by the company was in progress when this report was prepared.

A limited reconnaissance study was made of the Flower-Pot Shale exposures in northern Greer and Beckham Counties. Although available information is inconclusive, additional examination of the area appears warranted. Sample analyses are shown in appendix B (sample sites 17-25).

Texas

The three modes of copper deposition, previously described, occur in Texas. Copper minerals in Permian red beds, have been found in at least 15 Texas counties and in all of the three stratigraphic groups discussed earlier in this report. The copper occurrences are described in several reports (5; 7; 17; 26-27; 33; 36, 1910, p. 572, 1911, p. 739, 1912, p. 880, 1916, p. 212, 1917, p. 722, 1918, p. 328).

Copper occurrences in the Wichita Group, referred to in the literature, are in Archer, Clay, Montague, and Wichita Counties. The copper mineralization is associated with clay-shales and sandstone, and accompanying carbonaceous material is abundant. Thicknesses of the copper-bearing zones range from a few inches to about 4 feet and lateral extensions range from about 50 to 200 feet. The occurrences exhibit a typical channeling and scouring depositional environment. A few such deposits were a source of small tonnages of copper prior to 1900.

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[7] Copper production is company confidential.

In Archer County occurrences are associated with strata of the Wichita Group that crop out along the Little Wichita River 5 to 9 miles north and northwest of Archer City. Chalcocite, malachite, and azurite are the principal copper minerals. Comparable occurrences were found in Clay County north, northeast, and southeast of Henrietta along the drainages of Little Wichita and East Fork of Little Wichita Rivers. In Montague County similar occurrences occur in the vicinity of Belcherville along the drainage of a small tributary to Wichita River. In Wichita County, copper was found in the Wichita Group near the mouth of Gilbert Creek where it enters the Wichita River.

Copper has been found in the Clear Fork Group of sediments in nine localities in Baylor, Haskell, Jones, Taylor, Throckmorton, and Wilbarger Counties. These copper occurrences tentatively are classified as channel-scour deposits and are probably of limited areal extent. In Jones County a few miles northeast of Avoca, chalcocite and malachite, associated with carbonaceous material, occur in a clay-shale bed that crops out in the N 1/2 sec 190 Buffalo Bayou, Brazos, and Colorado Railroad Survey. A grab sample contained 0.19 percent copper. In general, landforms in the outcrop area of the Clear Fork Group exhibit low relief, and surface prospecting for copper is difficult.

Copper occurrences in the Double Mountain (Pease River) Group of sediments in Texas could be of economic significance. Deposits are in an elongated belt of outcrops extending southward from Hardeman County through Foard, Knox, King, and Stonewall Counties. The principal occurrences were found at surface altitudes ranging from about 1,480 to 1,650 feet; these altitudes were used as a guide in prospecting outcrops. Copper minerals were found in the lower and upper parts of the San Angelo Formation and the lower part of the Blaine Formation.

Copper occurs in sandstone and shale beds at the base of the San Angelo Formation. These copper occurrences are classified as paleoalluvial or deltaic environmental deposits; channeling and scouring were not noted.

Copper occurrences found in the Blaine were classified as channel scour and as lagoonal deposits in thin dolomite, mudstone, and shale beds immediately below gypsum beds, and in some sandstone horizons. (At least two separate copper-bearing horizons are known.) The lowest copper bearing zone of possible economic interest at the base of the Blaine exhibits features common to channel and scour deposits as well as basinal depositional features. An upper copper-bearing zone in the Blaine is associated with lagoonal environmental deposition but apparently is not as extensive as the lower Blaine copper zone. For purposes of description, the principal copper-bearing zones in the San Angelo and Blaine Formations in King and Knox Counties are designated A, B, and C.

In Hardeman County, in the area investigated, copper minerals are found primarily in the Blaine Formation, and also in parts of the San Angelo Formation. In Foard and Stonewall Counties, copper is found in both the San Angelo and Blaine Formations but the extent and nature of the deposits were not determined.

Copper deposits in southeastern Hardeman County flank a topographic prominence known as Medicine Mounds. Pertinent outcrop sample data are given in appendix B (sample sites 31-53). One copper-bearing zone in the Blaine Formation can be traced 9 miles southwest of the Mounds, although copper minerals are not everywhere visible in the outcrop. A copper deposit of limited size, known as the Gibbs prospect (appendix A, mine 6), is the channel-scour type of occurrence in a sandstone lens near the base of the Blaine Formation. This deposit was the source of copper ore produced in the county in 1918. Production consisted of 3 tons of hand-sorted ore containing 50 percent copper. It is estimated that the deposit contains only a few hundred tons of such high-grade ore, and consequently in itself would be noncommercial.

Occurrences having possible commercial potential in Hardeman County are associated with dolomite and shale beds in the Blaine Formation. The principal mineralized zone is 1 inch to 9 inches thick and is overlain by a 2- to 3-foot bed of gypsum. Drilling by the Bureu of Mines indicated that mineralization extends behind the outcrop; in the area investigated, the mineralized zone is covered by as much as 65 feet of overburden. Progressing northwestward from the outcrop, overburden thickens to as much as 190 feet assuming formational dips do not change; a regional dip of about 20 feet to the mile was observed.

Copper occurrences in Foard County were found from the Teacup Mountain area northward to Pease River in the north-central part of the county in two separate zones, both in or near the lower part of the Blaine Formation. The lower cupriferous zone, associated with lenticular sandstone beds, was the site of development for the McClellan Mine (appendix A, mine 5), where about 250 tons of ore was mined, concentrated, and smelted in facilities at the property. Exploration is needed to determine size and grade of the deposit. The deposit is tentatively classified as a channel-scour type covering several acres. An upper copper-bearing zone, about 50 feet above the lower zone, is in shale and gypsum beds. Outcrop thickness of the mineralized zone is about 8 inches. Copper-bearing exposures were traced laterally for several hundreds of feet. Extensive exploration is needed to determine size and grade of the deposit.

Copper deposits in Knox County were found in three widely separated areas, but absence of outcrops prevented adequate examination necessary to determine possible relationships.

Zone B.[8]--A cupriferous zone in the northernmost part of the county is about 5 miles west of Truscott and is confined to a gypsiferous sandstone lens and underlying shale bed; the zone is classified as a channel-scour type near the lower part of the Blaine Formation. Copper minerals are exposed in a 4-foot-thick zone in an open cut that is a circular shape with a diameter of about 200 feet. Drilling by the Bureau of Mines to determine possible down-dip extensions failed to reveal copper minerals at depth.

[8]Another zone B area containing copper mineralization is about 8 miles west of Benjamin in the west-central part of Knox County. The occurrence, classified as a channel-scour type, is of limited areal extent and apparently confined to a sandstone lens near the base of the Blaine Formation.

Zone A.--Reconnaissance westward from the B zone deposit revealed scattered copper minerals in shale, mudstone, and dolomite of the Blaine Formation for a linear distance of about 4 miles. Sample analyses are given in appendix B (sample sites 90-96). Geologic conditions are favorable for significant resources of copper in an area of about 6 square miles. Considerable exploration, however, is needed to evaluate the potential.

Zone C.--Copper-bearing sandstone and underlying shale in the San Angelo Formation outcrop for a linear distance of 2 to 3 miles in the southwest part in Knox County. The mineralized zone is 4 to 5 inches thick and drill cores indicate the zone persists in part behind the outcrop. Overburden thickness is less than 60 feet for distances of as much as 6,500 feet behind the outcrop. Additional appropriate exploration and sampling is needed to define potential ore bodies. This deposit is the northward extension of a comparable zone of copper mineralization of the C zone found in King County and is classified as being of the paleoalluvial fan or deltaic type of deposit.

The three modes of copper deposition described earlier in this report are found in King County.

Zone C.--The lowermost copper-bearing rocks exposed in the county are in the lower part of the San Angelo Formation. This copper-bearing bed can be traced almost continuously northeastward across King County into Knox County from a point just southwest of the corner common to King, Knox, Stonewall, and Haskell Counties for a linear distance of about 12 miles. The copper deposition is related to the deltaic environment of the host bed. Appendix B contains analyses of outcrop samples (sample sites 55, 64, 65, 68-73, 80-86, 88-89, 100-101). Copper-bearing seams measured as much as 7 inches thick. The host rock is mostly sandstone underlain by mudstone. The mineralized zone, referred to as zone C, was encountered in drill holes as far as 10,000 feet behind the outcrop. The zone has an apparent regional dip of about 30 feet per mile. Overburden thickness increases to as much as 200 feet at distances of about 2 miles behind the outcrop. In some scattered places near the outcrop line, groundwater leaching has apparently removed the copper.

Zone B.--A second copper-bearing zone in King County overlies zone C, and in this report is referred to as zone B. (See fig. 8.) This zone was traced along the outcrop discontinuously for an air-line distance of nearly 5 miles. Zone B is 50 to 80 feet stratigraphically above zone C and drilling indicated that the mineralization was discontinuous. Thickness of zone B appears to range from paper-thin films to as much as 5 feet. Host rock for the copper minerals includes dolomite, mudstone, and shale. The occurrence of channeling and scouring features, secondary gypsum and dolomite, and carbon trash and associated copper minerals, in addition to relatively widespread basinal depositional features, suggest that areal distribution of potential mining zones may be extensive but not continuous. Additional drilling would be necessary to delineate possible ore bodies.

Zone A.--A third cupriferous zone, designated zone A, occurs 15 to 50 feet stratigraphically above zone B and crops out discontinuously over an air-line distance of 7 miles. (See fig. 8.) Host rocks in this zone exhibit criteria that suggests classification as a basinal type of depositional environment. Cupriferous bodies are associated with host rocks of dolomite, mudstone, and shale; thickness of copper mineralization ranges from a few inches to as much as 7 feet. Channel and scour depositional characteristics were found in parts of outcrop area of zone A; however, the exact relationship of the copper deposition is unknown. Preliminary field studies in part suggest that channel-scour deposition is later and stratigraphically above zone A. Analysis for copper of cores from drilling through overburden to penetrate mineralized beds in zone A further substantiates the lack of continuity of mineralization over broad areas.

Two copper prospects have yielded a small quantity of ore. At both places, open cuts and short adits were excavated in channel-scour type deposits. Copper was found in zones A and B. In 1969, workings were caved and nearly obliterated by erosion. The properties were worked during World Wars I and II. Exact tonnage of output is not known but the meager information suggests that total output comprised less than 100 tons of hand-cobbed ore.

Southward extensions of copper-bearing strata found in zones B and C in King County crop out in northeast Stonewall County. Zone B appears to persist from the northern boundary of the county to a point south of the Salt Fork of Brazos River north of the town of Old Glory; linear distance is about 10 miles. Cupriferous zone C was traced a linear distance of about 3.5 miles from the northern limits of Stonewall County southward to a point just south of the junction of Panther Canyon and the Salt Fork of Brazos River. Although no detailed work was done by the Bureau of Mines, reconnaissance examinations and limited outcrop sampling suggest that further work is necessary to evaluate the potential because of comparable characteristics to other areas having known favorable potentials. Appendix B contains analysis of a few outcrop samples taken in Stonewall County. The copper occurrences in Stonewall County have geologic characteristics comparable to those associated with the B and C zones in King County; however, overburden thickens rapidly west of outcrop strike of zone B in Stonewall County. An unknown, but apparently small tonnage of copper ore was produced from one prospect in the northern part of the county during World Wars I and II. Shallow cuts and adits were opened in mining copper ore from the B zone in those instances where channel-scour conditions prevail. Copper occurrences were found in strata in the Double Mountain Group in southern Stonewall County and northern Fisher County, and further work is necessary for evaluation of deposits.

Drilling and Sampling

Core and noncore rotary drilling and attendant sampling was done at 38 sites in four counties in Texas--Hardeman, Knox, King, and Stonewall--to supply data of the copper occurrences away from the outcrop. The drilling was done in three areas described in this report as Medicine Mounds area--Hardeman County; Truscott area--Knox County; and Buzzard Peak area--King, Knox, and Stonewall Counties. Eight holes were drilled in the Medicine Mounds area, two in the Truscott area, and 28 in the Buzzard Peak area. Total footage drilled was 3,627.5 feet of which 1,927.5 feet was cored. Holes ranged in depth from 27.5 to 224.0 feet. Overall core recovery was 94 percent. Core recovery by drilling area--Medicine Mounds, Truscott, and Buzzard Peak--was 92.7, 94.0, and 95.0 percent, respectively. Drilling was done on nine separate properties; location, ownership information, logs, and sample analyses are given in appendix C. All drilling was done under contract with a private drilling company who used drilling equipment designed for either wet or dry core recovery. The drill rig had 1,000-foot depth rating and was equipped with a bypass line (using either compressed air or hydraulic pressure) to remove core from the barrel. The drilling contractor employed a two-man crew who worked one 10-hour shift 7 days per week. Drilling operations were started on November 11, 1968, and were ended on January 15, 1969. Periods of extended inclement weather occurred from November 25 to December 5, 1968, and from December 21, 1968, to January 3, 1969. At an early time following commencement of drilling operations in some locations, companion or nearby offset holes were drilled to test recovery of core by drilling under dry conditions or when loss of water circulation occurred at shallow depths. It was quickly determined that dry drilling operations were not satisfactory because core recovery was less than 50 percent, and wet drilling ensued. In those holes where water loss occurred, drilling mud additives were introduced to the drilling fluid; however, these instances were few and it was found that natural muds developed by drilling were satisfactory in sealing voids and returning cuttings to the surface. A principal objective of the drilling was to obtain core because mineralized zones are limited to a few inches in thickness and because facies changes and information on the details of overburden rock materials are significant.

Although a 10-foot double-wall core barrel was used, in most instances drill runs were limited to 5 feet to insure core recovery and because of the swelling nature of many of the clay and shale materials when wet. Figure 6 shows the drill rig and attendant water truck.

Hole locations were on a random pattern designed to determine mode of depositional environment of copper occurrences and sites were selected so as not to require road construction or site preparation.

Holes were started by using a 5-5/8-inch-diameter rock bit and as soon as consolidated rock was penetrated (usually 10 feet) the core barrel was attached. A sawtooth-type coring bit with tungsten carbide inserts on cutting faces having an outside diameter of 4-7/8 inches was used for drilling. Three-inch-diameter cores were obtained. Figure 7 shows recovered core. Cutting edges of bits remained sharp indicating little wear during the drilling of shale, mudstone, and loosely cemented sandstone, but signs of wear appeared when the bit penetrated thin beds of indurated sandstone and dolomite. In some instances, 1 to 4 hours was required to core-drill a foot of indurated sandstone or hard dolomite. Maximum rate for core drilling was 10.5 feet per hour and maximum penetration rate for rotary noncore drilling was 66.6 feet per hour. Average daily penetration rate for core and noncore drilling was 82.4 feet per 10-hour shift. Some holes were cored at alternating intervals of depth but most holes were cored from 10 feet to the ultimate depth.

Recovered core was removed from the core barrel and retained on half sections of lightweight-plastic drainpipe until qualitative field tests for

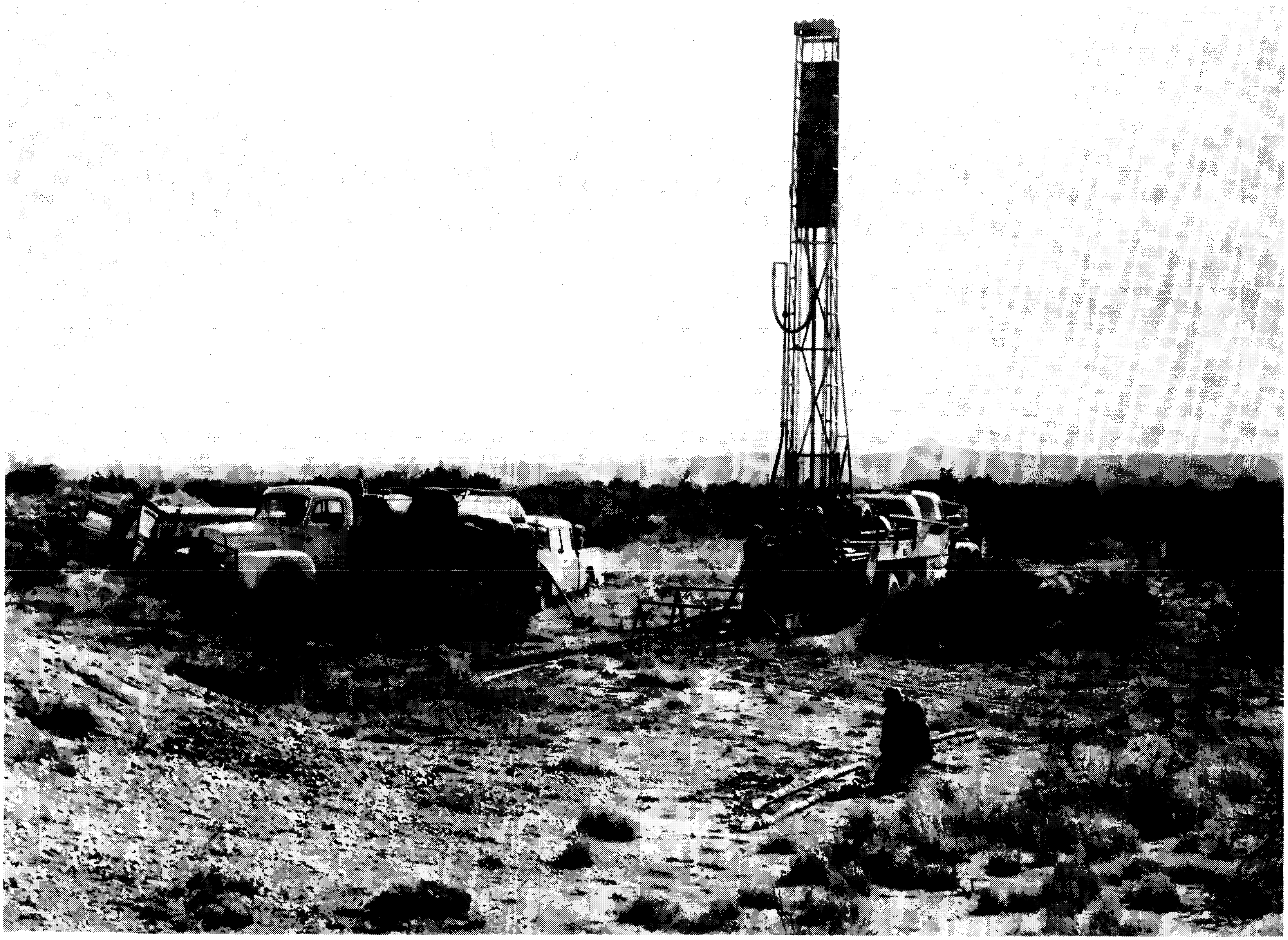

FIGURE 6. - Core Drill and Water Truck.

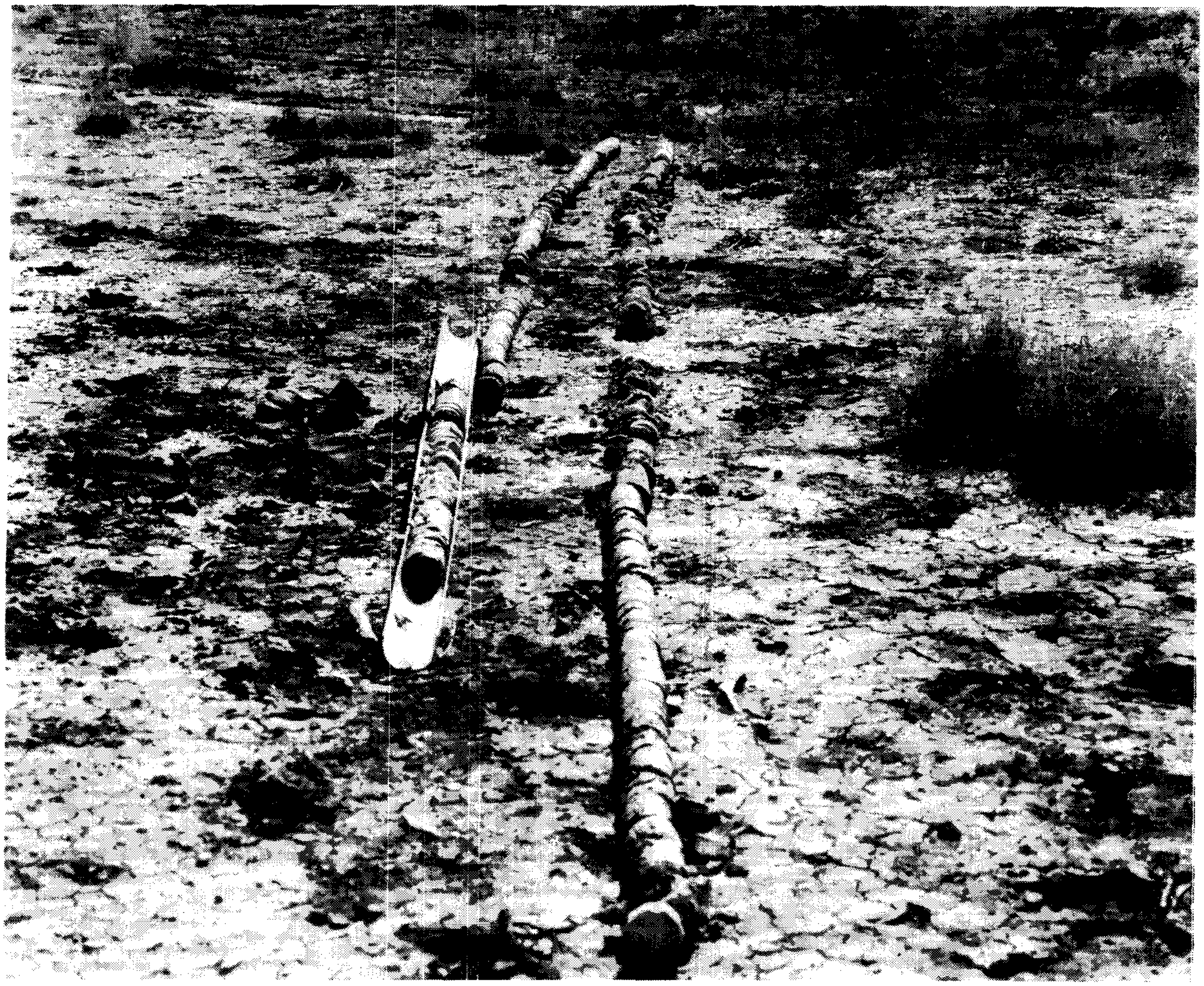

FIGURE 7. - Recovered Core From Drilling Operations.

copper were made. That part of the core showing a positive qualitative test for copper was placed in core boxes and later transferred to the Bureau facilities in Bartlesville, Okla. The core was later split and sample analyses were made at the Bureau of Mines Salt Lake City Metallurgy Research Center, Salt Lake City, Utah. After careful logging, unwanted core was discarded. Mineralized core splits were retained for viewing in the Bartlesville Office of Mineral Supply until 1972.

Data on 38 holes sampled are given in appendix C. Thickness of each interval is shown as is the copper analysis. The detailed logs indicate the rock type penetrated. Analyses indicate a copper content ranging from a trace (less than 0.01 percent) to 1.5 percent in 63 percent of the holes drilled, and in 23 percent of the holes copper values were 0.50 or more over intervals ranging from 0.3 foot to 5 feet.

Evaluation of Copper Deposits

General

Time was not available to examine all areas in western and northern Oklahoma, and it was not the intent of this investigation to eliminate possible economic significance. Reconnaissance of copper occurrences in southwest Kansas and in northern Oklahoma, supplemented by information from available reports, suggests that copper-bearing zones in these areas have less potential than those in Texas and southwest Oklahoma.

Evaluation of copper-bearing areas having possibly significant commercial potential, of necessity, was based upon cursory field examinations followed by relatively intensive field study and selective core drilling in selected areas. Core drilling activities were not intended for determining copper ore reserves. Holes were spaced rather widely and drilled on a random pattern. Drill-hole logs and sample analyses indicate frequent facies changes in formations and variation of copper content. Close-spaced drilling and detailed sampling will be necessary to evaluate copper resources in any area. Additional detailed or close-spaced drilling is prerequisite to preparing meaningful geologic cross sections of the areas drilled. Bureau of Mines drilling was not done in necessarily the best prospective areas; rather, the areas selected for drilling were considered to be representative of what might be expected as to mode of occurrence and potentials of copper deposition through the belt of the San Angelo and lower Blaine Formations extending southward from Red River in Hardeman County to the Double Mountain Fork of Brazos River in Stonewall County. Figure 8 is an idealized section of the copper-bearing horizons near the base of the Double Mountain Group in north-central Texas and southwest Oklahoma.

Medicine Mounds Area--Hardeman County

Eight holes were drilled in the area as shown in figure 9. Logs and copper analyses are given in appendix C. Analyses of outcrop samples are included in appendix B (sample sites 31-53). All holes were collared in strata of the Blaine Formation; collar elevations ranged from about 1,550 to 1,570 feet above sea level. Copper was detected in six of the eight holes which were drilled to depths ranging from 51 to 224 feet. Copper content ranged from 0.07 to 1.5 percent in an upper cupriferous zone that is covered with about 40 to 50 feet of overburden. This zone has an apparent maximum thickness of about 1.2 feet (14 inches). Samples from a lower cupriferous zone, about 5 feet below the upper zone and 0.3 to 0.5 foot thick contained from 0.04 to 0.20 percent copper in two holes.

Analyses of outcrop channel samples taken by the Bureau of Mines in the Medicine Mounds area have a copper content ranging from 0.01 to 3.65 percent. A review of these data and information derived from drill holes suggests that at least one cupriferous zone (upper) is continuous for a linear distance of about 4 miles and extends behind the outcrop for distances ranging from about one-fourth to one-half mile. Additional drilling and sampling would be necessary to determine exact lateral limits.

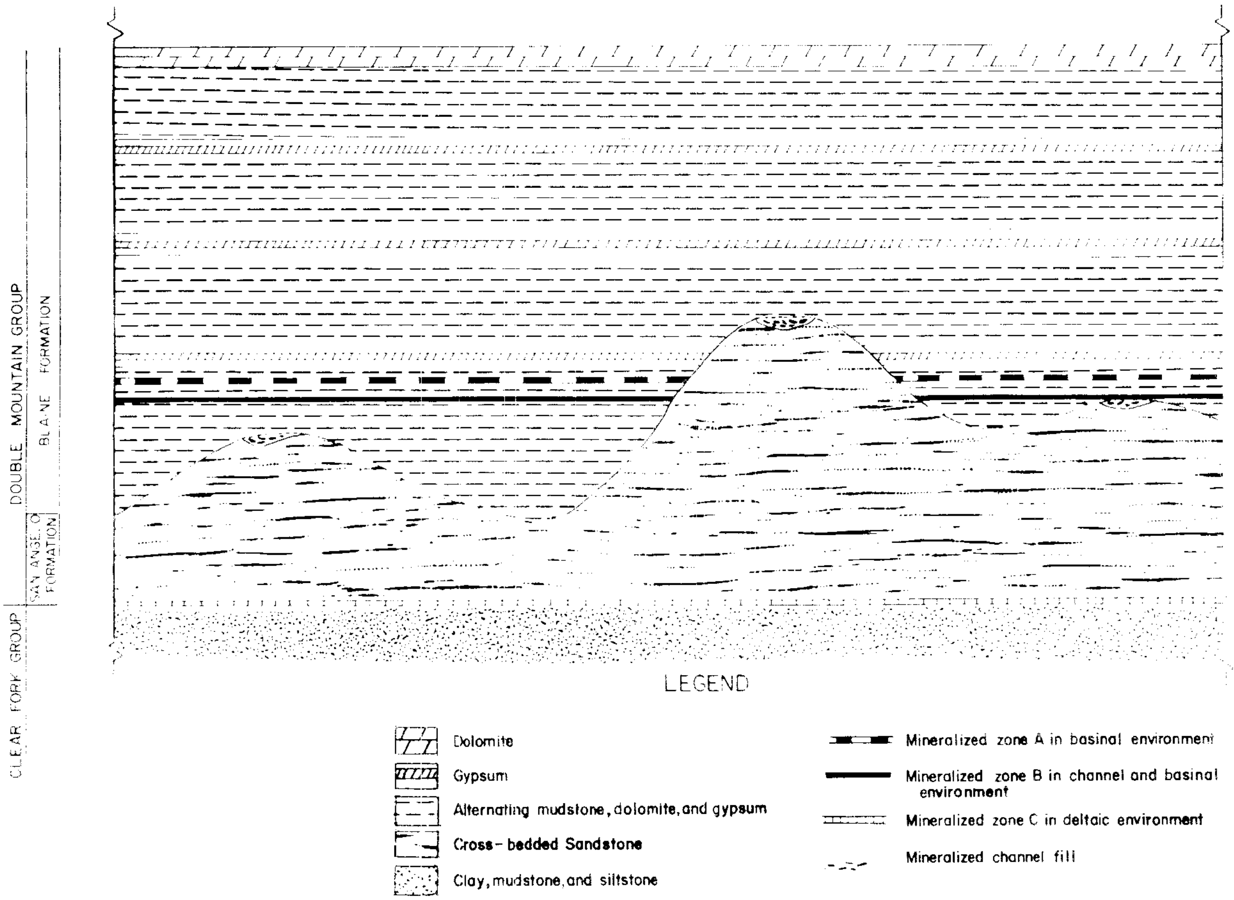

FIGURE 8. - Generalized Section of Copper-Bearing Beds Near the Base of the Double Mountain Group in North-Central Texas and Southwest Oklahoma.

Hole number E-8 was drilled about 9 miles northwest of the copper-bearing exposures in the Medicine Mounds area to determine possible extensions of mineralization at a greater distance behind the outcrop and to obtain additional geological data. Although no copper was detected, study of the rock units penetrated indicate that a broad correlation can be made of stratigraphic units in the area, particularly the gypsum beds.

Truscott Area--Knox County

Two holes were drilled in the area to test the continuity of a channel-type deposit associated with lenticular sandstone beds in the lower Blaine Formation. Appendix C contains logs of holes. No copper was detected in cuttings or core from either hole, thus exemplifying the vagaries of channel-type deposits. Copper content of samples taken from exposures in the area are given in appendix B (sample sites 90-96). Figure 10 shows drill hole and sample site locations.

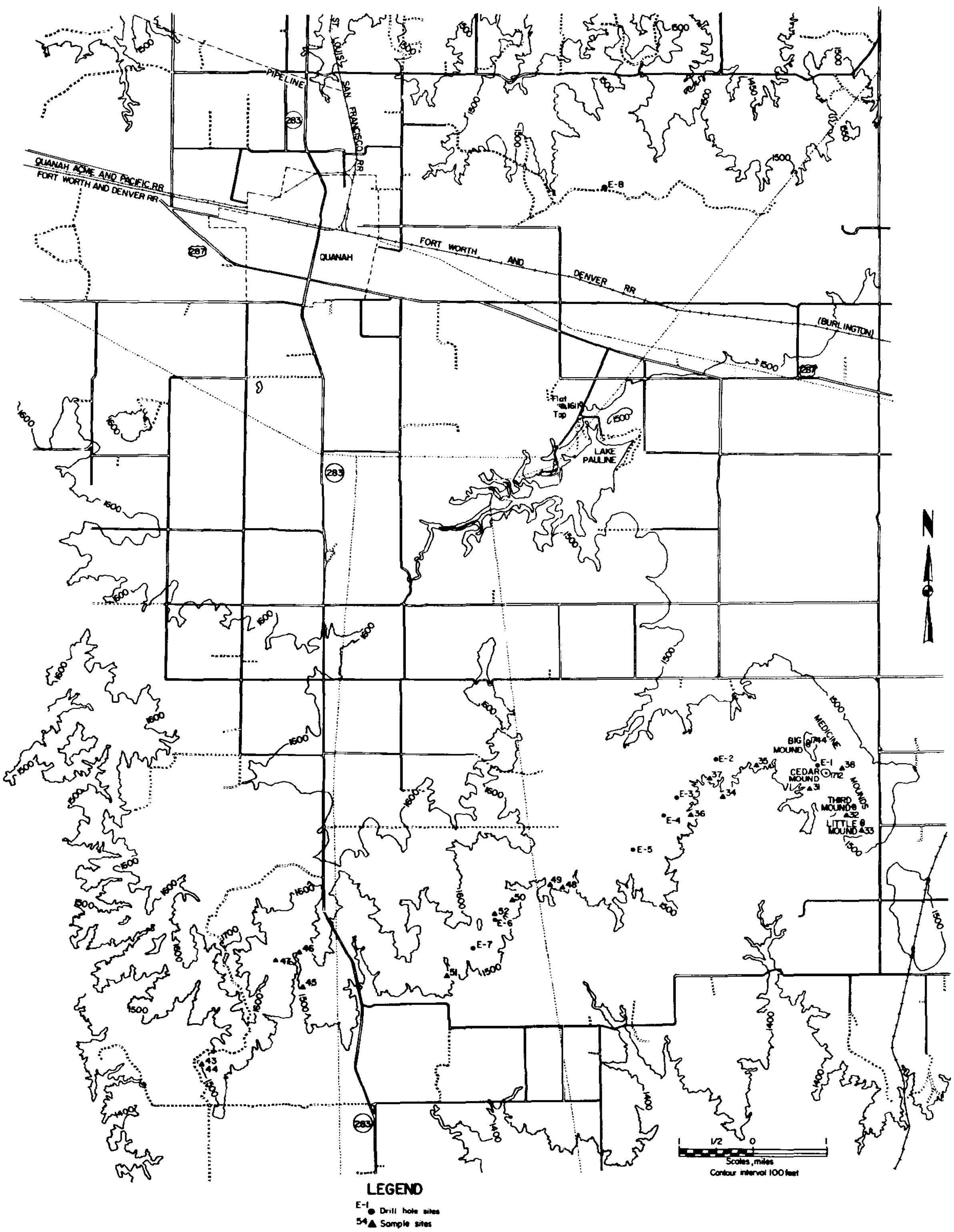

FIGURE 9. - Drill Hole and Sample Sites in Medicine Mounds Area, Hardeman County, Tex. (Source: Adapted from U.S. Geological Survey Topographic Map Division.)

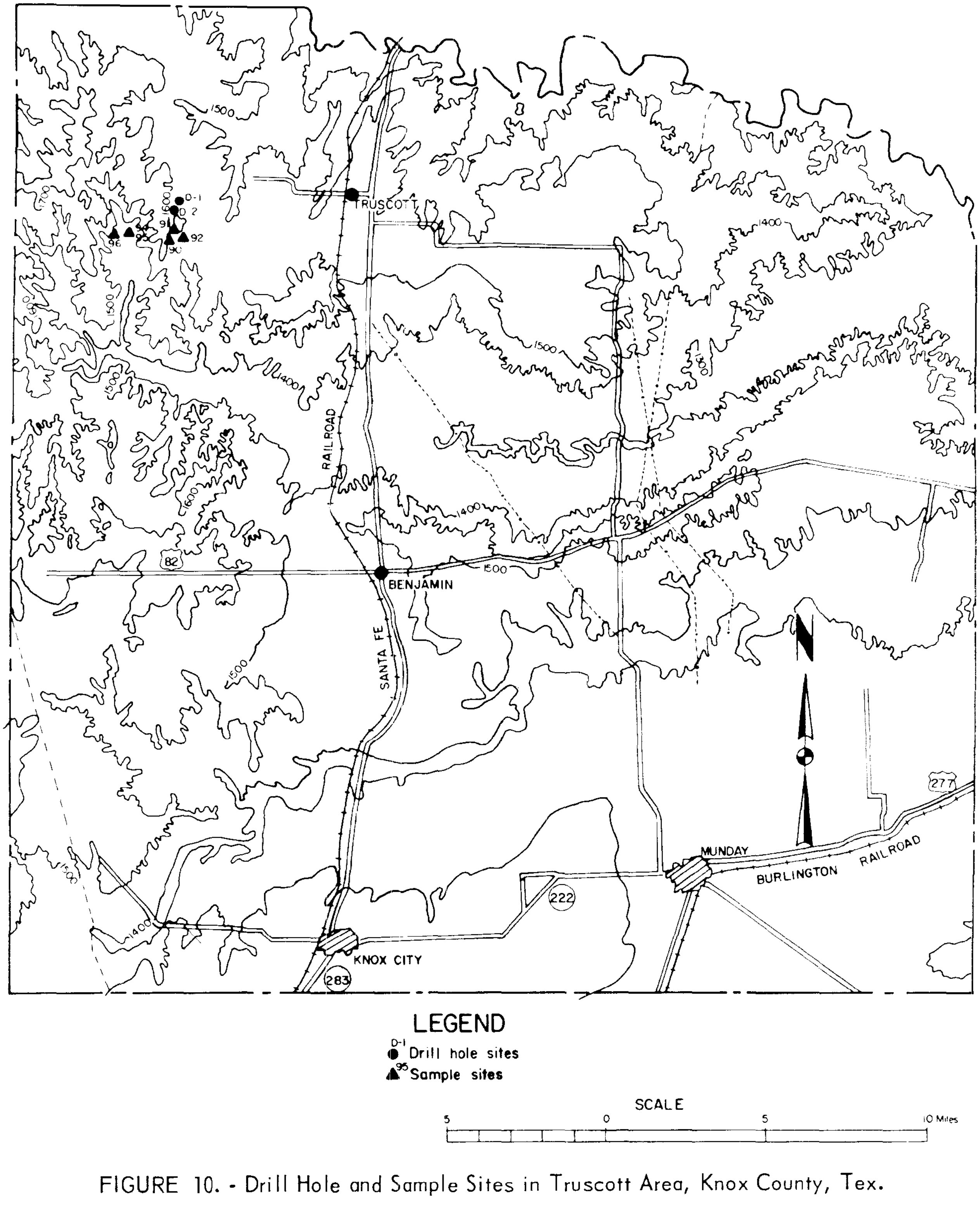

FIGURE 10. - Drill Hole and Sample Sites in Truscott Area, Knox County, Tex.

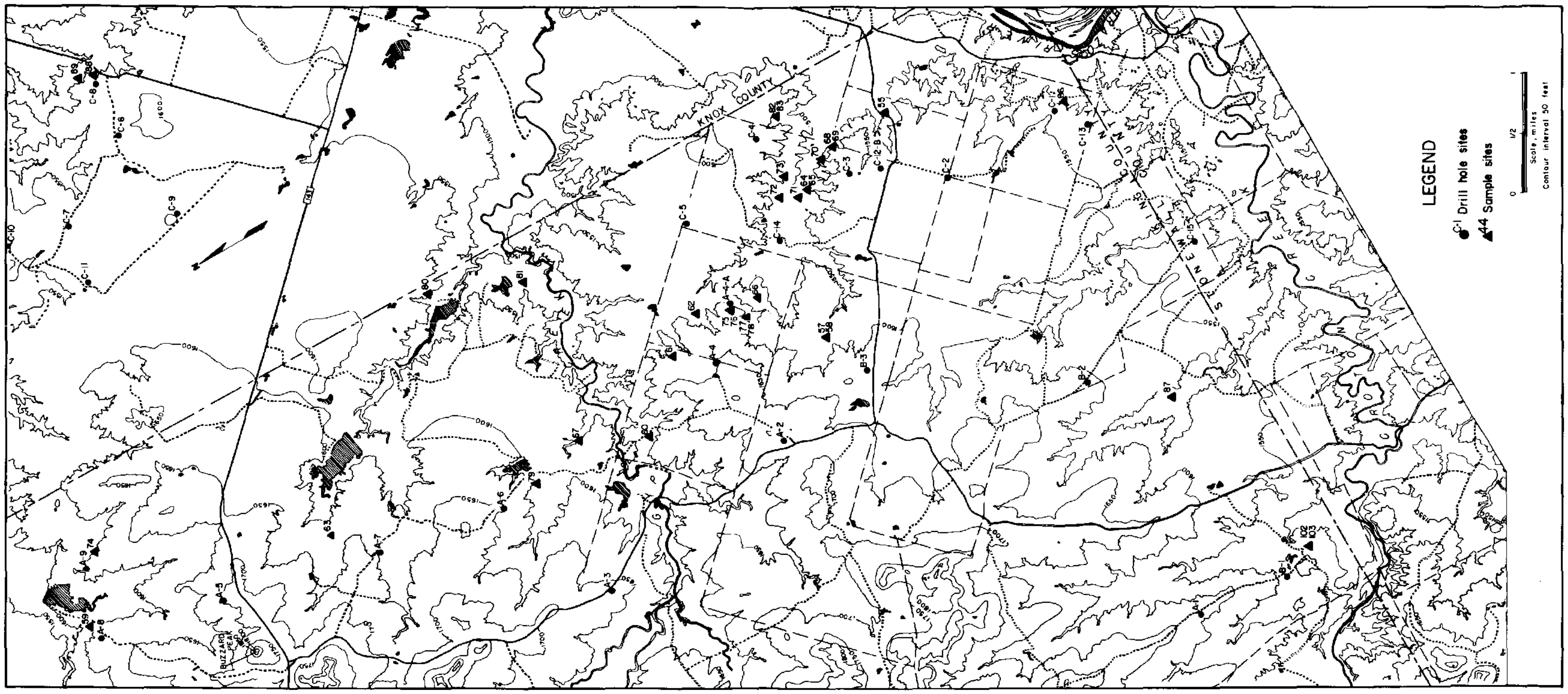

FIGURE 11. - Drill Hole and Sample Sites in Buzzard Peak Area, King, Knox, and Stonewall Counties, Tex. (Source–Adapted from U.S. Geological Survey Topographic Maps: Benjamin 3 S.W., Peacock 1 N.E., and Guthrie 4 S.E., Texas.)

Although no copper was found, additional investigation probably is warranted west of the drill site area. Westward from drill sites, copper was found in shale, mudstone, and dolomite beds. Additional work is necessary to evaluate completely the copper potential.

Buzzard Peak Area--King, Knox, and Stonewall Counties

Twenty-eight holes were drilled in the Buzzard Peak area aimed principally at determining the continuity of copper mineralization associated with the three modes of deposition. Location of drill holes is shown on figure 11. Logs of drill holes and copper analyses are given in appendix C. The holes were collared at various elevations ranging from about 1,535 to 1,700 feet in the Blaine and San Angelo Formations and were so placed to intersect at depth one or more of three mineralized horizons as projected from outcrops. Outcrop sample sites are shown on figure 11 and analyses are given in appendix C. Depths of holes ranged from 27.5 to 201 feet. Copper, ranging from a trace to 0.98 percent, was found in 17 of the 28 holes. One hole (A-4-A) penetrated 5 feet of mineralization containing an average 0.59 percent copper. Copper-bearing zone C, apparently the most persistent horizon, extends to at least 10,000 feet behind the outcrop.

Analyses of 38 outcrop samples indicate a copper content of <0.01 to 10.60 percent. A close-spaced drilling program in selected areas and some selective trenching along outcrop zones having scant overburden is necessary for adequate evaluation. The lowermost copper-bearing zone, near the base of the San Angelo Formation, is persistent over an outcrop length of about 12 miles and extends southward from southwest Knox County through southeast King County into northeast Stonewall County. (This zone also extends southward from the southernmost drill hole.) Copper-bearing zones A and B are apparently less extensive than zone C but thickness aspects (up to 5 feet of mineralization) in some places are favorable.

MINING AND MILLING METHODS AND ESTIMATED COSTS

General

In 1965, Eagle-Picher Industries, Inc., began and have sustained production in a profitable operation near Creta, Okla., demonstrating the feasibility of commercial production of copper from Permian red beds. The cost analysis data presented in the report further supports the thesis that copper recovery from Permian red beds can be commercial.

In anticipation that copper occurrences in the study area will have increasing interest and because mining factors appear favorable, a production program, including capital and operating cost estimates, was made for a representative ore body. Mining cost calculations provided for partial leveling of spoil banks and experimental plantings for revegetation.

Assumptions

Assumptions made in this section were that an ore deposit has been delineated that contains 2.8 million tons of mill ore having a head assay value of 0.90 percent sulfide copper and 0.295 percent nonsulfide copper. Geological conditions indicate that the ore body can be extended assuring ample tonnage to amortize the investment. It may also be postulated that additional ore bodies will be found. Also assumed was a mill recovery of 90 percent of the sulfides and 40 percent of the nonsulfides, or a total recovery rate of 77.6 percent. The overburden would range from near 0 to 60 feet, with an average of 35 feet. Production is proposed at the rate of 1,000 tons of ore per day, for a one-shift day and 5 days per week.

Because of the fine particle size of the contained copper minerals, the flotation process would be required for concentration. Flotation plants cannot operate economically in very small units, so a plant capacity of 1,000 tons per 24 hours, 5 days per week is proposed. Cost estimate of capital investment for such a plant, including the mine equipment and development is $2.5 million.

Ore of the assumed grade will gross the producer $6.13 per ton after deducting smelting charges, freight, royalty, and severance taxes[9] (8). Mining, milling, and smelting and incidental operating cost, with allowance for depreciation, was estimated as $5.10 per ton allowing a profit of $1.04 before taxes and depletion. A yearly income of $270,000, before income tax and depletion, could be expected.

Extraction

Mining

Strip-mining methods would be used. The general mining pattern would be row or parallel stripping, but limits of the stripped area will be controlled by excessive thickness of overburden. It is assumed that 60 feet of overburden would be the average maximum limit. A 15-cubic-yard electric dragline with 175-foot boom would be required. A large bulldozer would prepare a pathway for the dragline and also partially level the spoil banks. Drilling and blasting rock overburden would involve use of a rotary truck-mounted drill and an ammonium nitrate explosive.

The ore bed would be cleaned with a smaller dozer and resampled for thickness and grade. The ore seam would be "plowed" with a pulvamixer, which is a modified asphalt paving cutter. The machine literally rototills the ore to a maximum size of about 1 inch. A front-end loader would be used to stack the disintegrated material and load it into 10-ton dump trucks for transportation to the mill. Capacity of the operation is postulated at 1,000 tons of ore daily on a 5-day-per-week basis.

[9]Engineering and Mining Journal Markets. Copper: 42.114 Cents Per Pound. V. 169, No. 8, August 1968, p. 23.

Milling

Haulage trucks would discharge into a 500-ton subsurface hopper. The ore would be drawn with a pan feeder and fed directly into a 24-inch, jaw-type crusher. Most of the crude ore would pass through the crusher, but occasional fragments may require additional breakage. The crusher installation is deemed necessary even if other methods of mining were to be used or there was a change in the mineral matrix. Crusher capacity would be 1,000 tons per 8 hours.

Crushed ore would be conveyed from the crusher pit, passing under a tramp iron magnet, and discharged into a 24-inch hammer mill with 1/4-inch bar openings operating in closed circuit with a 1/4-inch, single-deck vibrating screen. All the ore would pass through the hammer mill to increase the percentage of fines and reduce the ball mill load. The mill heads would be sampled as the ore discharges into a 1,000-ton ore bin. Capacity of crushing unit was planned at 1,000 tons per 8 hours.

Ore from the secondary crusher would be drawn from the storage bin and carried on a variable-speed belt feeder to two 6- by 6-foot ball mills operating in closed circuit with screw-type classifiers. Water from the supply pond would be introduced at this point and a slurry density of about 25 percent solids might be required to insure efficient ball mill operation. Grinding to 200 or 300 mesh is required to free the mineral particles. Ball mill grinding would be at the rate of 500 tons per 24 hours.

Pulp from the ball mills would discharge into a conditioner where lime would be added in proper amounts to maintain the degree of alkalinity desired for the flotation circuit. Conditioner capacity would be 1,000 tons of ore in a 25-percent-solid solution per 24 hours.

The conditioned pulp would be pumped (or flow by gravity) into two rougher flotation units. Each unit would have eight cells with a capacity of 630 tons of solids per 24 hours. Froth from the first two rougher cells would be sent to the cleaner section; froth from the other cells would be returned to the first rougher cells for recleaning. Tailings would discharge into the storage pond. The flotation cleaner section would be a four-cell unit discharging the first cell froth to the thickener, returning the froth of the other cells for upgrading, and routing the tails back to the ball mill circuit.

Froth from the cleaner would be settled and thickened in a spiral rake classifier and pumped to a disc filter. The filter cake would pass to a 3- by 12-foot butane-fired rotary dryer, where concentrates would be partially dried to reduce freight costs. Production would be planned for 25.0 tons of 40-percent-copper concentrates per 24-hour day.

For a 24-hour day:

1,000 tons of mine ore treated
23.2 tons of concentrates produced
976.8 tons of tailings to storage pond

Water requirements:

To maintain 25 percent pulp density--500 gal/min
Make up water estimated--100 gal/min

Figures 12 and 13 represent typical flowsheets. Pertinent cost analysis data are given in appendixes D and E.

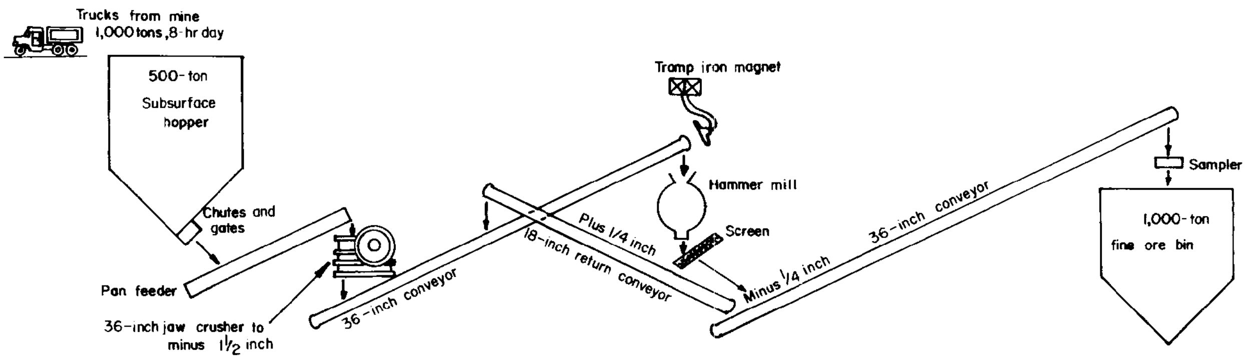

FIGURE 12. - Proposed Flowsheet of Copper Concentrator (Primary-Secondary Crushing).

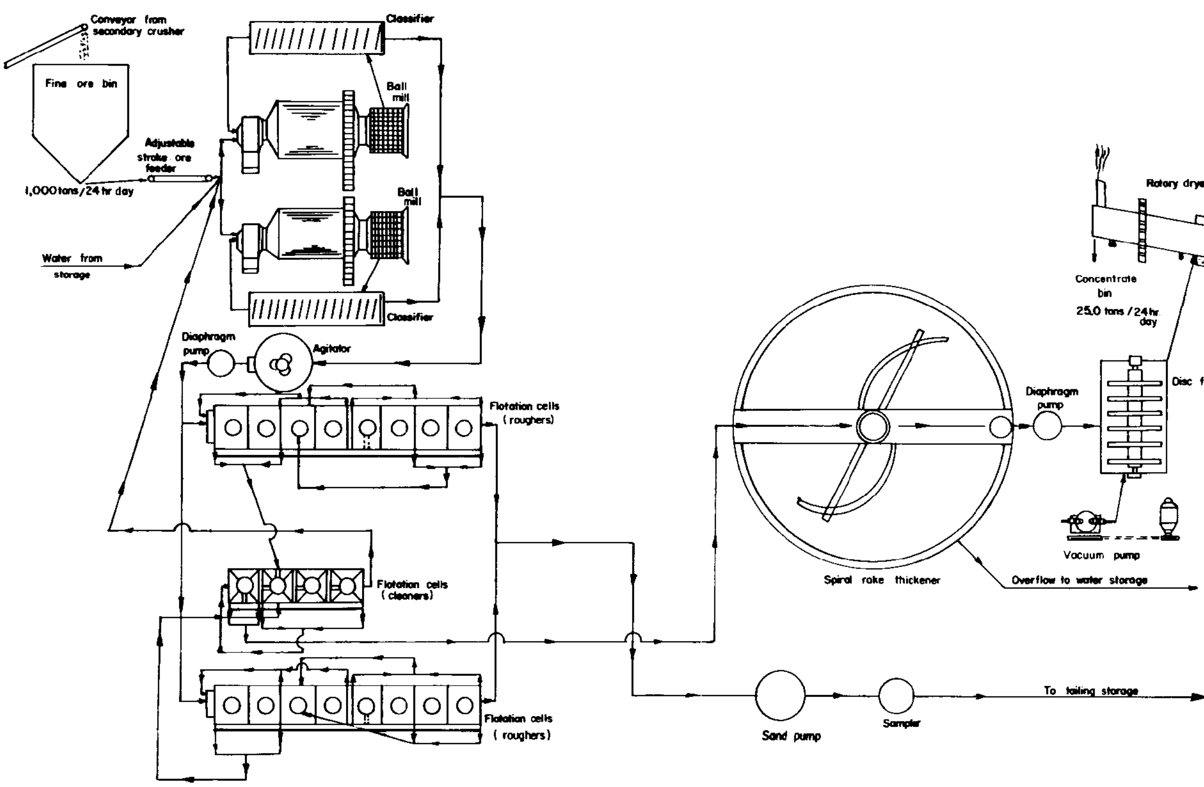

FIGURE 13. - Proposed Flowsheet of Copper Concentrator (Fine Grinding-Flotation).

The foregoing cost analysis data are based on the premise that the copper ore contains a preponderance of copper sulfide in relation to oxidized copper minerals. However, because a substantial part of the copper deposits in some parts of the study area are altered to oxides, it is appropriate to discuss briefly another economically feasible means of concentrating copper from deposits described in this report. Also, the reader should be cognizant that other research efforts may eventually result in new economical methods of treatment and recovery.

The leaching precipitation-flotation process (L-P-F) briefly described here may be applicable for use for those copper ores that are mixed sulfides and oxides having an oxide content of as much as 40 percent. Although cost analyses are not presented here, such data can be developed (1). It is assumed that use of the L-P-F process would result in higher copper recovery for mixed sulfide-oxide ores but that corresponding higher costs in processing would result. Research would be necessary to determine possible benefits.

In a typical L-P-F process system, copper oxide minerals are dissolved with sulfuric acid. The copper in solution can be precipitated as metallic sponge which is concentrated by conventional means. The sulfide content of a mixed ore is insoluble and the pregnant leach solution thus contains copper both as a sulfide and in dissolved form as copper sulfate.

Conventional crushing and grinding equipment can be used to prepare the ore for leach treatment. Following passage of the ore through a leaching system, metallic iron is added to precipitate the copper in solution to finely divided copper sponge. Both copper sponge and sulfide copper are introduced into a conventional flotation system and the final product is thickened and filtered.

Experimentation with a particular ore is necessary to achieve the best results; however, the L-P-F concentrating process can result in greater overall copper recovery from mixed sulfide-oxide copper ores.

CONCLUSIONS

Based upon extensive reconnaissance over wide areas of exposed copper-bearing Permian formations, sampling of copper-bearing outcrops, appraisal of formerly productive prospects, familiarity of a currently active operation, a limited core-drilling and attendant sampling program, production costs estimates, and development of basic information related to principal modes of occurrence of copper mineralization, it is concluded that copper occurrences in southwest Oklahoma and north-central Texas have good potential for commercial development. Copper occurrences in correlative formations of the Permian section in northwest Oklahoma and Kansas are insufficiently explored which precludes complete evaluation of potential.

Outcrop examinations and sampling indicated that copper of economic significance is confined to three stratigraphic zones: base of San Angelo Formation, top of San Angelo and base of Blaine Formations, and in a zone above the Blaine-San Angelo contact but in the lower part of the Blaine

Formation (correlative with the Flower-Pot). Principal mode of occurrences, closely related to depositional environments of enclosing host rocks, are deltaic deposits, basinal deposits, and channel-scour deposits. Deltaic deposits, although relatively thin, appear to be extensive and contain considerable copper. Basinal deposits are less extensive, appear to have uniform copper content, and have thicknesses that range from a few inches to as much as 5 feet. Channel-scour deposits have wide variety in size and thickness, commonly are higher in grade, but are the least attractive from a long-range mining viewpoint. Field observations of geological evidence suggests an epigenetic origin for present-day copper deposits associated with sediments in the Clear Fork and Wichita Groups appear to be less extensive than those in the Double Mountains Group and are considered, at this time, of little economic significance.

The Bureau of Mines drilling program was limited to testing the extensiveness of the three main types of copper occurrences at selected areas. Future exploration would require close-spaced drilling to determine grade, attitude, and extent of potential ore bodies. In drilling, cores 3 inches in diameter were satisfactory for this investigation. Ore bodies can be found containing copper in the range of 0.5 to 1.5 percent; in some areas a higher tenor may be expected. Other metals present of possible interest include silver, vanadium, nickel, lead, gallium, titanium, and zirconium; of these, only silver appears to have commercial possibilities.

Copper mineralization is comprised of mixed sulfides and oxides with sulfides dominant. Mining and milling methods are conventional but could be adapted to particular characteristics of ore bodies. Cost analyses data, for hypothetical situation as designed and evaluated for this investigation, suggest that ore grade material for a 1,000-ton-per-day mine and mill complex should contain 0.8 to 1.2 percent copper.

Additional geologic studies appear warranted to verify preliminary data gathered in the course of study and further to define criteria concerning mode of occurrence of copper. Because of the characteristics of deltaic-type copper occurrences, in situ leaching research presents a possible new approach toward exploiting this resource.

Zone C, because of its persistent lateral extent and apparently favorable lithologic characteristics, seemingly offers a potential target for in situ solution mining. The mineralized zone consists of an upper seam of cross-bedded, apparently porous sandstone and a lower seam of dense mudstone. Research appears warranted to test the nature of permeability and porosity, leachability and other essential criteria necessary to develop an effective extractive process. Other research efforts could be directed toward improved metallurgical recovery methods.

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APPENDIX A.--SIGNIFICANT RED BED COPPER "MINES AND PROSPECTS" IN OKLAHOMA AND TEXAS

Mine or prospect number	Name	Location: County	Location: State	Location: Legal description	Periods of operation	Copper production	Remarks	References
1......	Teepee Queen..	Garvin...	Okla.	SW 1/4 SW 1/4 sec. 18, T. 4 N., R. 1 E.	1913	Undetermined	Production from two side-hill cuts is reported as "a few tons."	36, 1913, p. 159
2......	Lobaris.......	Greer....	do..	Secs. 2, 5, 8, and 12, T. 3 N., R. 22 W., and sec. 27, T. 4 N., R. 22 W.	1963 to present	([1])	Construction of a crushing and flotation plant was underway at time of report preparation.	
3......	Creta.........	Jackson..	do..	Secs. 3, 4, 9, 10, 15, and 16, T. 1 S., R. 22 W.	1965 to present	([1])	Strip mine and flotation mill operating.	18 12
4......	Byars.........	McClain..	do..	SE 1/4 sec. 33, T. 5 N., R. 2 E.	1897-1898 1913-1914	219 tons crude ore (7,487 fine oz. of silver)	Mine workings consist of one strip pit 100x150 ft., one adit and one shallow shaft.	36, 1914, p. 114 20, p. 6
5......	McClellan.....	Foard....	Texas	Sec. 37, Blk. A, Texas and New Orleans RR Co. Survey[2]	1877-1917 1943-1945 1967 to present	250 tons crude ore	A mill and smelter was constructed in 1877. Mining was done from adits (tunnels) driven from an open cut. At present, exploration is in progress.	36, 1917, p. 722 27
6......	Gibbs.........	Hardeman.	do..	Sec. 85, Blk. H, Waco and Northwestern RR Co. Survey	1918	100 tons crude ore	One side-hill cut, one adit and one shallow shaft.	
7......	Buzzard Peak..	King.....	do..	Sec. 1, J. G. Eustis Survey	1882-1945	2,550 tons crude ore (in part from Stonewall Co.)	Mine workings consist of two pits and one adit. A mill was constructed in 1917.	26, p. 645
8......	Brazos-Wichita	do.....	do..	Sec. 86, Blk. 13, Houston and Texas Central RR Co. Survey	1917	40 tons crude ore	Mine workings consist of a side-hill cut. A mill was constructed in 1917.	36, 1917, p. 722 35, 36, 1918, p. 328
9......	McFaddin......	Knox.....	do..	Sec. 29, Blk. 13, Houston and Texas Central RR Co. Survey	1945	None	A leaching plant consisting of 3 12-foot concrete tanks--no mine development.	
10......	Pyron (Craig Ranch).	do.....	do..	Sec. 26, Blk. 4, Dallas and Wichita RR Co. Survey	Prior to 1911	Undetermined "several cars" (1916)	Mine workings consist of four adits. A mill was constructed at the site.	36, 1911, p. 739 36, 1916, p. 212 26, p. 645
11......	Smelter Mine (Pyron Prospect).	do.....	do..	Sec. 6, P. Goldberg Survey, A-557, Gulf, Colorado, and Santa Fe RR Co.	1880-1945	1,000 tons crude ore	Mine workings consist of one adit. A two-cell jig and a smelter was constructed by Goldberg Mining Co. in 1880.	36, 1911, p. 739 36, 1912, p. 880 4, p. 454 27, p. 97 5, p. 235
12......	Copper Queen..	Stonewall	do..	Secs. 20 and 21, Blk. A, Arnold and Barrett Survey	1880-1892 and 1945	175 tons crude ore (1890)	Mine workings consist of 5 adits. At present, exploration is in progress.	
13......	Aard Copper, Inc. (Farris Copper Prospect).	do.....	do..	F. Davidson Survey	1965 to present	65 tons crude ore	Mine workings consist of numerous adits and open cuts.	24
14......	Hugh-Rogers (Smelter Canyon or Kiowa Peak).	do.....	do..	Sec. 2, Buffalo Bayou, Brazos and Colorado RR Co. Survey	1882-1945	Undetermined	Mine workings consist of a strip pit and two adits. A mill was operated at the mine site.	

[1]Company confidential.
[2]Land surveys in Texas were established by Texas General Land Office in 1837; surveys were made by various railroad companies (6).

APPENDIX B.--OUTCROP SAMPLES OF COPPER-BEARING STRATA

Sample site	USBM sample No.	Location: State	Location: County	Location: Legal description	Ownership	Geologic formation	Type: Sample	Type: Rock	Thickness (inches)	Analysis (copper, percent)
1	C-15	Okla.	Beckham	SW 1/4 sec. 14, T. 8 N., R. 22 W.	VanVactor Ranch	Blaine	Chip-channel	Shale	15	0.05
2	C-16	do	do	SW 1/4 sec. 13, T. 8 N., R. 22 W.	do	do	do	do	10	.06
3	C-1	do	Garvin	Center south line, sec. 7, T. 4 N., R. 1 E.	State Highway	Wellington	do	Sandstone	18	14.40
4	C-2	do	do	SW 1/4 sec. 18, T. 4 N., R. 1 E.	J.T. Wigley Ranch	do	Grab	do	([1])	8.60
5	C-3	do	do	SW 1/4 sec. 7, T. 4 N., R. 1 E.	do	do	Chip-channel	do	40	.34
6	C-4	do	Greer	SW 1/4 sec. 27, T. 4 N., R. 22 W.	Meadows Ranch	Blaine	do	Shale	12 (top)	.85
7	C-5	do	do	do	do	do	do	do	8 (middle)	.40
8	C-6	do	do	do	do	do	do	do	4 (bottom)	.25
9	C-7	do	do	NW 1/4 sec. 10, T. 4 N., R. 22 W.	Cupp Ranch	do	do	do	12 (top)	.29
10	C-8	do	do	do	do	do	do	do	4 (middle)	.80
11	C-9	do	do	do	do	do	do	do	8 (middle)	.18
12	C-10	do	do	do	do	do	do	do	8 (bottom)	.02
13	C-11	do	do	NE 1/4 sec. 2, T. 3 N., R. 22 W.	Meadows Ranch	do	do	do	20	1.00
14	C-12	do	do	NW 1/4 sec. 12, T. 3 N., R. 22 W.	do	do	do	do	18	.11
15	C-13	do	do	SE 1/4 sec. 5, T. 3 N., R. 22 W.	do	do	do	do	32	.80
16	C-14	do	do	NW 1/4 sec. 8, T. 3 N., R. 22 W.	do	do	do	do	18	.50
17	C-17	do	do	SW 1/4 sec. 10, T. 7 N., R. 23 W.	Fowler Ranch	do	do	do	14	.36
18	C-18	do	do	1/4 mile east of above site	do	do	do	do	24	.22
19	C-19	do	do	SE 1/4 sec. 10, T. 7 N., R. 23 W.	do	do	do	do	16	.02
20	C-20	do	do	NE 1/4SE-1/4 sec. 10, T. 7 N., R. 23 W.	do	do	do	do	8 (top)	.23
21	C-21	do	do	do	do	do	do	do	8 (bottom)	.04
22	C-22	do	do	SW 1/4 sec. 11, T. 7 N., R. 23 W.	Scott Ranch	do	do	do	10	.46
23	C-23	do	do	NE 1/4 sec. 15, T. 7 N., R. 23 W.	do	do	do	do	6	.65
24	C-24	do	do	NE 1/4 sec. 18, T. 7 N., R. 23 W.	Reed Ranch	do	do	do	8	.11
25	C-25	do	do	NW 1/4 sec. 18, T. 7 N., R. 23 W.	do	do	do	do	8	.05
26	RAF-6	Texas	Foard	NW 1/4 sec. 82, Blk. 44, Houston and Texas Central RR Co. Survey[2].	Fain-Brown Ranch	San Angelo	do	Sandstone	4	.29
27	RAF-7	do	do	Sec. 12, Blk. A, Southern Pacific RR Co. Survey.	Johnson, Ekern Ranch.	Blaine	do	Mudstone	8	.35
28	RAF-8	do	do	Sec. 37, Blk. A, Texas and New Orleans RR Co. Survey.	do	do	Grab sample, mine-run ore	Sandstone, mudstone.	([1])	1.40
29	RAF-9	do	do	Sec. 2, San Antonio and Mexican Gulf RR Co. Survey.	do	do	Chip-channel	Sandstone	8	1.05
30	RAF-10	do	do	do	do	do	do	Mudstone	8	1.10
31	RAF-1	do	Hardeman	NW 1/4 sec. 62, Blk. H, Waco and Northwestern RR Co. Survey.	Brown Ranch	do	do	Shale	6	.90
32	RAF-2	do	do	NE 1/4 sec. 62, Blk. H, Waco and Northwestern RR Co. Survey.	do	do	do	do	6	1.25
33	RAF-3	do	do	SE 1/4 sec. 62, Blk. H, Waco and Northwestern RR Co. Survey.	do	do	do	do	6	1.15
34	RAF-4	do	do	NE 1/4 sec. 85, Blk. H, Waco and Northwestern RR Co. Survey.	do	do	do	Sandstone	14	1.00
35	RAF-5	do	do	SE 1/4 sec. 85, Blk. H, Waco and Northwestern RR Co. Survey.	do	do	do	Shale	10	.18
36	RAF-55	do	do	SE 1/4 sec. 86, Blk. H, Waco and Northwestern RR Co. Survey.	do	do	do	do	8	1.25

37....	RAF-56	do..	...do...	Center south line, sec. 86, Blk. H, Waco and Northwestern RR Co. Survey.	........do.......	....do....	......do.....	.......do.......	22	.80
38....	RAF-89	do..	...do...	NW 1/4 sec. 62, Blk. H, Waco and Northwestern RR Co. Survey.	........do.......	....do....	......do.....	Mudstone........	8	1.15
39....	RAF-54	do..	...do...	W 1/2 sec. 2, East Line and Red River RR Co. Survey.	Hafner Ranch.....	San Angelo	Channel......	Shale, sandstone	17	.40
40....	RAF-84	do..	...do...	Hopkins County School Land, A-14, Tract 14.	Holcomb Ranch....	Blaine....	Chip-channel.	Gypsum..........	8	.01
41....	RAF-85	do..	...do...	150 ft north of above site........	........do.......	....do....	Channel......	Mudstone........	6	.21
42....	RAF-86	do..	...do...	................do................	........do.......	....do....	......do.....	Shale, dolomite.	2	.49
43....	RAF-87	do..	...do...	Hopkins County School Land, A-15, Tract 3.	........do.......	....do....	......do.....	.......do.......	8	.09
44....	RAF-88	do..	...do...	200 ft northwest of above site....	........do.......	....do....	......do.....	Shale...........	6	.05
45....	RAF-90	do..	...do...	Hopkins County School Land, A-14, S 1/2, Tract 12.	........do.......	....do....	Chip channel.	Shale, mudstone.	6	.33
46....	RAF-91	do..	...do...	Hopkins County School Land, A-14, N 1/2, Tract 12.	........do.......	....do....	......do.....	.......do.......	5	.04
47....	RAF-92	do..	...do...	Hopkins County School Land, A-14, Center E Line, Tract 9.	........do.......	....do....	......do.....	Limestone, mudstone.	8	.13
48....	RAF-57	do..	...do...	Sec. 10, East Line and Red River RR Co. Survey.	Hurst Ranch......	....do....	......do.....	Shale...........	10	.17
49....	RAF-58	do..	...do...	SE 1/4 sec. 10, East Line and Red River RR Co. Survey.	........do.......	....do....	......do.....	.......do.......	18	.50
50....	RAF-59	do..	...do...	SW 1/4 sec. 10, East Line and Red River RR Co. Survey.	........do.......	....do....	Channel......	.......do.......	7	.80
51....	RAF-62	do..	...do...	Hopkins County School Land, A-14..	........do.......	....do....	......do.....	.......do.......	8	3.65
52....	RAF-60	do..	...do...	................do................	Williams Ranch...	....do....	......do.....	.......do.......	6	2.75
53....	RAF-61	do..	...do...	................do................	........do.......	....do....	......do.....	.......do.......	8	1.65
54....	RAF-17	do..	Jones...	N 1/2 sec. 190, Buffalo Bayou, Brazos and Colorado RR Co. Survey	Stenholm Ranch...	Clear Fork Group.	Grab.........	.......do.......	([1])	.19
55....	RAF-13	do..	King....	Sec. 88, Blk. 13, Houston and Texas Central RR Co. Survey.	Unknown..........	San Angelo	Chip-channel.	Sandstone, mudstone.	7	1.40
56....	RAF-20	do..	...do...	200 ft northeast of site above....	........do.......	....do....	Chip.........	Shale...........	10	.02
57....	RAF-23	do..	...do...	Sec. 86, Blk. 13, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	Blaine....	Grab.........	Mill tailings...	([1])	1,95
58....	RAF-67	do..	...do...	Center sec. 86, Houston and Texas Central RR Co. Survey.	........do.......	....do....	Channel......	Shale, dolomite, carbonized wood and gypsum.	12	10.60
59....	RAF-24	do..	...do...	Sec. 112, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	Chip-channel.	Shale...........	10	.33
60....	RAF-25	do..	...do...	NE 1/4 sec. 84, Blk. 13, Houston and Texas Central RR Co. Survey.	Ross Ranch.......	....do....	......do.....	.......do.......	6	.03
61....	RAF-26	do..	...do...	SE 1/4 sec. 84, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	......do.....	.......do.......	24	.65
62....	RAF-27	do..	...do...	NE 1/4 sec. 83, Blk. 13, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	....do....	......do.....	.......do.......	8	.38
63....	RAF-28	do..	...do...	SW 1/4 sec. 1, J.G. Eustis Survey.	Ross Ranch.......	....do....	Trench.......	Grab mine-run ore (shale).	Unknown (mineral-ized shale zone, 8 ft thick).	1.20

See footnotes at end of table.

Sample site	USBM sample No.	Location: State	Location: County	Location: Legal description	Ownership	Geologic formation	Type: Sample	Type: Rock	Thickness (inches)	Analysis (copper, percent)
64....	RAF-29	Texas	King....	NE 1/4 sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey.	Hendrix Ranch....	San Angelo	Channel......	Shale..........	6	0.39
65....	RAF-30	do..	...do...	SW 1/4 sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	......do.....	.......do.......	6	.18
66....	RAF-31	do..	...do...	SW 1/4 sec. 83, Blk. 13, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	Blaine....	......do.....	.......do.......	8	1.10
67....	RAF-32	do..	...do...	NW 1/4 sec. 75, Blk. 13, Houston and Texas Central RR Co. Survey.	Arnold Ranch.....	....do....	......do.....	.......do.......	6	.24
68....	RAF-43	do..	...do...	SE 1/4 sec. 87, Blk. 13, Houston and Texas Central RR Co. Survey.	Hendrix Ranch....	San Angelo	Chip-channel.	Sandstone.......	7	.23
69....	RAF-44	do..	...do...	...............do...............	........do.......	....do....	......do.....	Mudstone........	6	.09
70....	RAF-45	do..	...do...	SW 1/4 sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	Channel......	.......do.......	6	<.01
71....	RAF-46	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	8	.12
72....	RAF-47	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	7	.19
73....	RAF-48	do..	...do...	...............do...............	........do.......	....do....	......do.....	Shale, mudstone.	7	<.01
74....	RAF-68	do..	...do...	NE 1/4 sec. 111, Blk. 13, Houston and Texas Central RR Co. Survey.	McElroy Ranch....	Blaine....	......do.....	Shale..........	8	.55
75....	RAF-69	do..	...do...	Center sec. 83, Blk. 13, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	....do....	Chip-channel.	Shale, mudstone.	8 (top of 5-ft section)	.02
76....	RAF-70	do..	...do...	...............do...............	........do.......	....do....	......do.....	Mud galls.......	8 (bottom of 5-ft section)	1.75
77....	RAF-71	do..	...do...	500 ft southwest of above site....	........do.......	....do....	Channel......	Shale, mudstone.	9 (top of 5-ft section)	.50
78....	RAF-72	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	9 below sample of RAF-71	.95
79....	RAF-73	do..	...do...	SE 1/4 sec. 96, Blk. 13, Houston and Texas Central RR Co. Survey.	Ross Ranch.......	....do....	......do.....	Shale..........	6 from 4-ft section-top and bottom eroded	.85
80....	RAF-74	do..	...do...	SE 1/4 sec. 72, Blk. 13, Houston and Texas Central RR Co. Survey.	Arnold Ranch.....	San Angelo	......do.....	Shale, mudstone.	8	.47
81....	RAF-75	do..	...do...	NW 1/4 sec. 71, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	......do.....	Shale, sandstone	6	.55
82....	RAF-76	do..	...do...	NW 1/4 sec. 81, Blk. 13, Houston and Texas Central RR Co. Survey.	Howell Ranch.....	....do....	......do.....	Shale, mudstone.	6	.27
83....	RAF-77	do..	...do...	NE 1/4 sec. 81, Blk. 13, Houston and Texas Central RR Co. Survey.	........do.......	....do....	......do.....	.......do.......	6	<.01
84....	RAF-78	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	6	.02
85....	RAF-79	do..	...do...	SW 1/4 sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey.	Hendrix Ranch....	....do....	......do.....	.......do.......	6	.40
86....	RAF-82	do..	...do...	SW 1/4 sec. 89, Blk. 13, Houston and Texas Central RR Co. Survey.	Hardwick Ranch...	....do....	......do.....	Sandstone, shale, mudstone	6	1.40
87....	RAF-83	do..	...do...	SW 1/4 sec. 259, Blk. F, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	Blaine....	......do.....	Shale, mudstone.	6	.05

88...	RAF-11	do..	Knox....	Sec. 29, Blk. 13, Houston and Texas Central RR Co. Survey.	McFaddin Ranch...	San Angelo	Chip-channel.	Sandstone.......	4	0.75
89...	RAF-12	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	5	.55
90...	RAF-33	do..	...do...	Sec. 26, Blk. 4, Dallas and Wichita RR Co. Survey.	Alexander Ranch..	Blaine....	Grab.........	Shale (mine-run ore).	([1])	2.45
91...	RAF-34	do..	...do...	...............do...............	........do.......	....do....	......do.....	Shale (mill tails).	([1])	.25
92...	RAF-35	do..	...do...	...............do...............	........do.......	....do....	Channel......	Shale...........	6	<.01
93...	RAF-36	do..	...do...	Secs. 2, 3, 4, and 5, Blk. X, Adams, Beaty, and Moulton Survey.	Various..........	....do....	Selected.....	Copper sulfide nodules.	([1])	35.8
94...	RAF-37	do..	...do...	NW 1/4 sec. 5, Blk. X, Adams, Beaty, and Moulton Survey.	Lowrence Ranch...	....do....	Channel......	Dolomite........	4	1.60
95...	RAF-38	do..	...do...	...............do...............	........do.......	....do....	......do.....	Mudstone........	5	.07
96...	RAF-39	do..	...do...	SW 1/4 sec. 5, Blk. X, Adams, Beaty, and Moulton Survey.	........do.......	....do....	Grab.........	Dolomite........	([1])	3.75
97...	RAF-14	do..	Stonewall	D. Martindale Survey, A-410.......	McFarland Ranch..	....do....	Chip-channel.	Mudstone........	48	1.20
98...	RAF-15	do..	...do...	W.F. Maury Survey, A-450..........	A.R. Sawyers Ranch.	....do....	......do.....	.......do.......	17 (top of section)	6.10
99...	RAF-16	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	10 (bottom of section)	2.10
100...	RAF-21	do..	...do...	Texas and New Orleans RR Co. Survey, A-455.	J.B. Wilde.......	San Angelo	......do.....	Shale...........	8	.14
101...	RAF-22	do..	...do...	...............do...............	........do.......	....do....	......do.....	.......do.......	6	.37
102...	RAF-80	do..	...do...	SE 1/4 sec. 255, Blk. F, Houston and Texas Central RR Co. Survey.	6666 Ranch.......	Blaine....	Channel......	Shale, mudstone.	6	.04
103...	RAF-81	do..	...do...	...............do...............	........do.......	....do....	Grab.........	Clay, gypsum....	([1])	1.15
104...	K-1...	Kans.	Harper..	NW 1/4 sec. 18, T. 31 S., R. 5 W..	County Highway...	Wellington	Chip-channel.	Shaley dolomite.	6	.23
105...	K-2...	do..	...do...	SE 1/4 SE 1/4 sec. 29, T. 32 S., R. 5 W.	........do.......	....do....	......do.....	.......do.......	6	.04
106...	K-3...	do..	...do...	West line SW 1/4 SW 1/4 sec. 13, T. 34 S., R. 6 W.	........do.......	....do....	......do.....	.......do.......	12	.03
107...	K-4...	do..	...do...	West line NW 1/4 sec. 24, T. 34 S., R. 6 W.	........do.......	....do....	......do.....	.......do.......	8	.02

[1]Data not available.
[2]Land Surveys in Texas were established by Texas General Land Office in 1837; surveys were made by various railroad companies (6).

APPENDIX C.--LOGS OF BUREAU OF MINES DRILL HOLES

Buzzard Peak Area, King County, Texas
6666 Ranch

(Sec. 256, Blk. F, Houston and Texas Central RR Co. Survey)

Hole No. A-1

Drilling begun: January 11, 1969
Drilling completed: January 14, 1969

Collar elevation (approximate): 1625 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Red clay.
2.0	4.0	Gypsum.
4.0	6.0	Green and gray gypsiferous shale.
6.0	7.0	Gypsum.
7.0	9.0	Dark gray shale with gypsum stringers.
9.0	10.0	Gypsum.

Core Drill

Depth, feet		Formation
From-	To-	
10.0	12.4	Gypsum.
12.4	12.6	Dolomite.
12.6	13.5	Green and brown gypsiferous shale.
13.5	15.0	Shaley gypsum.
15.0	22.0	Gypsum.
22.0	22.2	Dolomitic shale.
22.2	22.4	Dolomite
22.4	23.6	Blue-gray gypsiferous shale.
23.6	24.6	Gypsum.
24.6	26.6	Blue-black gypsiferous shale.
26.6	28.4	Shaley gypsum.
28.4	33.4	Blue-gray shale.
33.4	35.0	Brown clayey shale.
35.0	35.8	Variegated blue and brown gypsiferous shale.
35.8	41.6	Blue-gray gypsiferous shale.
41.6	43.4	Variegated blue and brown, gypsiferous shale.
43.4	45.0	Bluish-gray gypsiferous shale.
45.0	47.2	Brown gypsiferous shale.
47.2	48.7	Bluish-gray gypsiferous shale.
48.7	50.0	Brown gypsiferous shale.
50.0	52.0	Gypsum.
52.0	55.1	Brownish-gray and bluish-gray gypsiferous shale.
55.1	55.2	Gray dolomite.
55.2	56.2	Blue-gray and reddish-brown shale.

Hole No. A-1 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
56.2	59.3	Gypsum.
59.3	60.6	Bluish-gray gypsiferous shale.
60.6	62.2	Reddish-brown shale.
62.2	63.1	Variegated brown and blue gypsiferous shale.
63.1	67.4	Gypsum.
67.4	71.6	Blue and brown gypsiferous shale.
71.6	75.6	Variegated blue, brown and green gypsiferous shale.
75.6	78.9	Brown mudstone.
78.9	79.1	Greenish-gray dolomite.
79.1	82.4	Variegated brown and green gypsiferous mudstone.
82.4	82.8	Green to brown dolomite.
82.8	83.0	Grayish-green mudstone.
83.0	90.0	Brown and green gypsiferous mudstone.
90.0	90.1	Dolomite.
90.1	97.0	Variegated brown and bluish gray mudstone.
97.0	100.0	Alternating blue-gray and brown mudstone and gypsum.
100.0	105.0	Variegated brown and blue gypsiferous mudstone.
105.0	106.2	Reddish-brown mudstone.
106.2	107.7	Blue-green and reddish-brown gypsiferous mudstone.
107.7	111.0	Variegated brown and bluish-green cross-bedded siltstone.
111.0	112.4	Cross-bedded blue-green gypsiferous sandstone.
112.4	113.4	Blue-green gypsiferous siltstone.
113.4	123.1	Blue-green and reddish-brown gypsiferous mudstone.
123.1	125.0	Alternating gypsum, and brown and blue-green gypsiferous mudstone.
125.0	131.4	Red and brown mudstone.
131.4	134.3	Blue-green and brown gypsiferous mudstone.
134.3	135.0	Variegated blue-green and brown silty mudstone.
135.0	136.4	Brown mudstone.
136.4	136.8	Blue-green mudstone.
136.8	136.9	Dolomite shale.
136.9	142.7	Blue-green and brown mudstone.
142.7	143.1	Greenish-gray gypsiferous cross-bedded sandstone.
143.1	144.0	Greenish-gray, dolomitic mudstone.
144.0	145.0	Greenish-gray and brown gypsiferous mudstone.
145.0	146.4	Blue-green and brown gypsiferous sandstone.
146.4	150.0	Blue-green and brown gypsiferous siltstone.

Analysis, percent

No copper detected.

(Sec. 85, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-2

Drilling begun: January 15, 1969
Drilling completed: January 15, 1969
Collar elevation (approximate): 1685 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	3.0	Brownish-black soil and brown clay.
3.0	4.0	Gypsum.
4.0	5.0	Red clayey shale.
5.0	8.0	Green shale.
8.0	9.0	Greenish-gray shale.
9.0	11.0	Gray gypsiferous shale.
11.0	12.0	Brownish-green shale.
12.0	14.0	Gray shale.
14.0	18.0	Gray-green shale.
18.0	19.0	Gypsum with green shale.
19.0	22.0	Blue shale.
22.0	23.0	Blue-black shale.
23.0	25.0	Gray shale.
25.0	28.0	Blue-gray gypsiferous shale.
28.0	29.0	Gypsum.
29.0	30.0	Gray shale.
30.0	31.0	Blue-gray shale.
31.0	33.0	Greenish-gray shale.
33.0	34.0	Gypsum.
34.0	35.0	Greenish-gray shale.
35.0	38.0	Bluish-green shale.
38.0	39.0	Brown shale.
39.0	40.0	Bluish-green shale.
40.0	43.0	Red shale.
43.0	45.0	Gypsum with green shale.
45.0	47.0	Green shale.
47.0	50.0	Red shale.
50.0	51.5	Gypsum.
51.5	52.5	Dolomite.
52.5	53.0	Gypsum.
53.0	54.0	Red and green shale.
54.0	59.0	Gypsum.
59.0	62.0	Green, gray and brown shale.
62.0	63.0	Gypsum.
63.0	64.0	Greenish-gray and red shale.

Hole No. A-2 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
65.0	65.5	Gypsum.
65.5	68.0	Green shale.
68.0	70.0	Brown shale with gypsum stringers.
70.0	75.0	Green gypsiferous shale.
75.0	78.0	Blue-green shale.

Core Drill

78.0	79.6	Red shale.
79.6	80.6	Gypsum and blue gypsiferous shale.
80.6	81.7	Red shale.
81.7	82.4	Gypsum.
82.4	85.0	Blue gypsiferous shale.
85.0	86.4	Blue-gray, brown and red gypsiferous shale.
86.4	89.6	Gypsum.
89.6	89.7	Gray dolomite.
89.7	90.0	Blue-gray and red gypsiferous shale.
90.0	93.2	Brown, gray and blue-green gypsiferous shale.
93.2	95.5	Gypsum.
95.5	96.4	Blue-green gypsiferous shale.
96.4	100.0	Red swelling shale.
100.0	105.0	Red shale.
105.0	105.5	Red and green gypsum.
105.5	110.0	Blue-green, red and brown gypsiferous mudstone.
110.0	111.6	Brown and variegated blue and brown mudstone.
111.6	115.0	Blue-gray gypsiferous mudstone with dolomite stringers.
115.0	124.3	Blue-green, red and brown gypsiferous mudstone.
124.3	124.7	Hard dolomitic gypsum.
124.7	125.0	Variegated brown and blue-green mudstone.

Analysis, percent

No copper detected.

(Sec. 95, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-3

Drilling begun: January 9, 1969 Collar elevation (approximate): 1650
Drilling completed: January 9, 1969 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brownish-black clay soil.
1.0	2.5	Red clay.
2.5	3.0	Gypsum.
3.0	4.0	Red clay shale.
4.0	5.0	Gypsum.
5.0	7.0	Green clay.
7.0	8.0	Brown clay.
8.0	9.0	Brown shale.
9.0	10.0	Brown shale and gypsum.

Core Drill

10.0	11.0	White shaley gypsum.
11.0	11.6	Dolomite.
11.6	12.0	Dolomitic shale.
12.0	13.4	Red clay shale.
13.4	20.0	Gypsum with red shale streaks.
20.0	22.1	Gypsum.
22.1	23.7	Gray clayey shale with gypsum streaks.
23.7	30.6	Brown and greenish-gray clayey shale, with gypsum streaks.
30.6	32.6	Blue-gray gypsiferous shale and dolomite.
32.6	35.0	Brown clayey shale.
35.0	35.3	Variegated blue and brown clayey shale.
35.3	35.5	Gray dolomite.
35.5	42.0	Bluish gray and brown shale with gypsum stringers.
42.0	45.0	Brown clayey shale.
45.0	45.5	Hard red shale.
45.5	47.5	Clayey gypsum.
47.5	49.9	Red clayey gypsiferous shale.
49.9	50.8	Clayey gypsum.
50.8	51.8	Blue-gray gypsiferous shale.
51.8	57.5	Red clayey gypsiferous shale.
57.5	59.8	Clayey gypsum.
59.8	59.9	Dolomite.
59.9	67.2	Blue-green and brown gypsiferous shale.
67.2	69.6	Gypsum.
69.6	70.0	Blue-green and brown clayey shale.

Hole No. A-3 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
70.0	74.5	Red shale.
74.5	75.9	Blue-green gypsiferous sandstone.
75.9	77.4	Brown siltstone.
77.4	77.8	Blue-green carbonaceous siltstone.
77.8	81.0	Blue-green and brown gypsiferous shale.
81.0	82.0	Blue-green siltstone with gypsum stringers.
82.0	85.8	Brown to red and blue-green gypsiferous mudstone.
85.8	88.4	Gypsum.
88.4	91.5	Brown silty mudstone.
91.5	92.5	Brown, blue and gray clayey siltstone.
92.5	94.0	Red gypsiferous mudstone.
94.0	100.3	Blue and brown gypsiferous mudstone.
100.3	101.8	Greenish-gray dolomite with gypsum plates.
101.8	102.8	Brown and green platy dolomite.
102.8	105.2	Gray dolomite.
105.2	106.4	Blue-green and brown gypsiferous shale.
106.4	107.5	Blue-gray siltstone.
107.5	112.5	Brown gypsiferous mudstone.
112.5	116.0	Blue-green and brown mudstone with hard silty streaks.
116.0	117.3	Brown, green and reddish brown mudstone.
117.3	118.4	Gypsiferous dolomite.
118.4	120.0	Reddish-brown and blue-green silty, gypsiferous mudstone.
120.0	124.1	Red clayey mudstone.
124.1	125.8	Blue-green and brown gypsiferous mudstone.
125.8	127.8	Red shale.
127.8	128.0	Shaley dolomite.
128.0	130.0	Blue-green and reddish-brown, gypsiferous mudstone.
130.0	140.0	Red gypsiferous mudstone.
140.0	145.6	Brown, blue and red clayey gypsiferous mudstone.
145.6	146.6	Brown clayey shale.
146.6	147.2	Brown and blue clayey shale.
147.2	155.0	Blue-gray to green gypsiferous, cross-bedded sandstone.

Analysis, percent

		Cu
97.0	97.3	.03
97.3	97.6	.10

Buzzard Peak Area, King County, Texas
Ross Ranch

(Sec. 84, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-4

Drilling begun: December 16, 1969
Drilling completed: December 16, 1969
Collar elevation (approximate): 1645 feet above sea level

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown gypsiferous soil.
1.0	3.0	Gypsum.
3.0	4.0	Green shale.
4.0	8.0	Green gypsiferous shale.
8.0	9.0	Brown shale.
9.0	10.0	Gypsum.

Core Drill

10.0	11.2	Shaley gypsum.
11.2	13.5	Gray and brown gypsiferous shale.
13.5	15.6	Red shale.
15.6	19.7	Gray and red gypsiferous shale.
19.7	22.9	Gypsum.
22.9	25.0	Blue gypsiferous shale.
25.0	29.0	Red gypsiferous shale.
29.0	30.0	Blue gypsiferous shale.
30.0	31.3	Gypsum.
31.3	33.3	Greenish-gray gypsiferous shale.
33.3	37.0	Red shale.
37.0	40.0	Red, green and brown gypsiferous shale.
40.0	42.3	Gray and green gypsiferous shale.
42.3	47.3	Brown and red shale.
47.3	50.0	Variegated green and brown shale with gypsum streaks.
50.0	55.0	Green and brown gypsiferous shale.
55.0	57.2	Gray-green, silty, gypsiferous shale.
57.2	58.0	Gray-green and brown shale.
58.0	60.0	Brown shale.
60.0	60.8	Red and variegated blue and brown shale.
60.8	65.0	Brown shale.
65.0	70.0	Variegated brown and red and gray-green gypsiferous shale.
70.0	75.0	Red gypsiferous shale.

Hole No. A-4 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
55.0	55.5	.01
55.5	56.0	.03
56.0	56.5	.04
56.5	57.0	.03
57.0	57.5	.01
57.5	58.0	.02

Buzzard Peak Area, King County, Texas
6666 Ranch

(Sec. 83, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-4-A

Drilling begun: December 17, 1968 Collar elevation (approximate):
Drilling completed: December 18, 1968 1655 feet above sea level

Rotary Drill

Depth, feet		Formation
From-	To-	
0	0.5	Brown soil.
0.5	2.0	Gypsum.
2.0	4.0	Green shale.
4.0	5.0	Brown shale.
5.0	8.0	Green shale.
8.0	9.0	Green and brown shale.
9.0	10.0	Gypsum.
10.0	14.0	Green gypsiferous shale.
14.0	17.0	Brown and green shale.
17.0	20.5	Gypsum.
20.5	22.5	Green shale.
22.5	25.0	Brown shale.

Core Drill

25.0	25.8	Gray gypsiferous shale.
25.8	29.3	Brown clayey shale.
29.3	30.0	Mottled, green gypsiferous shale.
30.0	31.6	Gypsum.
31.6	32.8	Gray gypsiferous shale.
32.8	35.0	Brown and gray shale.

Hole No. A-4-A (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
35.0	38.5	Red gypsiferous shale.
38.5	39.0	Green and brown mottled, gypsiferous shale.
39.0	44.0	Brown and gray gypsiferous shale.
44.0	47.3	Gray and brown shale.
47.3	53.0	Blue-green and brown gypsiferous shale.
53.0	53.3	Dolomite.
53.3	53.4	Siltstone.
53.4	53.6	Gypsum.
53.6	55.0	Gray and brown mottled shale.
55.0	60.0	Blue-green shale.
60.0	61.5	Greenish-gray dolomite with shale bands.
61.5	62.8	Gray-green dolomitic shale.
62.8	63.8	Reddish-brown shale.
63.8	65.0	Gray-green gypsiferous shale.
65.0	65.5	Gray and brown siltstone.
65.5	70.0	Brown gypsiferous shale.
70.0	74.7	Red shale.
74.7	77.8	Green, brown and gray siltstone.
77.8	78.4	Red shale.
78.4	78.5	Green gypsiferous shale.
78.5	78.7	Dolomite.
78.7	79.5	Green gypsiferous shale.
79.5	80.0	Brown mudstone.

Rotary Drill

80.0	83.0	Red shale.
83.0	84.0	Green gypsiferous shale.
84.0	87.0	Brown shale.
87.0	90.0	Green and brown shale.
90.0	93.0	Green gypsiferous shale.
93.0	95.0	Green and brown shale.
95.0	99.0	Brown shale.
99.0	100.0	Variegated green and brown shale.
100.0	101.0	Green shale.
101.0	102.0	Variegated green and brown shale.
102.0	111.0	Brown gypsiferous shale.
111.0	119.0	Brown and green shale.
119.0	121.0	Green shale and gray sandstone.
121.0	128.0	Gray sandstone.
128.0	131.0	Green, gray and brown shale.
131.0	132.5	Sandstone.

Hole No. A-4-A (cont'd)

Rotary Drill

Depth, feet From-	To-	Formation
132.5	136.0	Green shale.
136.0	138.0	Brown shale.
138.0	142.0	Green gypsiferous shale.
142.0	145.0	Brown gypsiferous shale.
145.0	146.0	Sandstone.
146.0	151.0	Green shale.

Core Drill

151.0	152.0	Green gypsiferous sandstone.
152.0	156.0	Variegated red and green gypsiferous shale.
156.0	165.1	Greenish-gray, cross-bedded, gypsiferous sandstone with shale streaks.
165.1	165.6	Brown gypsiferous shale.
165.6	165.8	Greenish-gray siltstone.
165.8	166.0	Gypsiferous, clayey sandstone.
166.0	166.6	Blue-green shale.
166.6	167.8	Brown shale.
167.8	171.0	Brown, gray and blue gypsiferous shale.

Analysis, percent

From-	To-	Cu
55.0	55.5	.74
55.5	56.0	.98
56.0	56.5	.48
56.5	57.0	.84
57.0	57.5	.55
57.5	58.0	.42
58.0	58.5	.58
58.5	59.0	.52
59.0	59.5	.44
59.5	60.0	.36
60.0	60.3	.09
77.0	77.3	<.01
77.3	77.6	<.01
77.6	77.9	.04
77.9	78.1	<.01
78.1	78.4	<.01
164.6	164.9	<.01
164.9	165.0	.21

(Sec. 112, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-5

Drilling begun: January 3, 1969 Collar elevation (approximate):
Drilling completed: January 5, 1969 1700 feet above sea level

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Gray gypsiferous clay.
2.0	4.0	Gray shale.
4.0	8.0	Gypsum.
8.0	15.0	Gray-green gypsiferous shale.
15.0	16.0	Gypsum.
16.0	19.0	Red shale.
19.0	23.0	Gray-green gypsiferous shale.
23.0	24.5	Brown shale.
24.5	28.0	Green shale.
28.0	39.0	Brown gypsiferous shale.
39.0	43.0	Green gypsiferous shale.
43.0	45.0	Gypsum.
45.0	46.0	Green shale.
46.0	48.0	Brown shale.
48.0	52.0	Shaley gypsum.
52.0	56.0	Gypsum.
56.0	58.0	Brown shale.
58.0	60.0	Gypsum.
60.0	63.0	Green shale.
63.0	67.0	Brown shale.
67.0	79.0	Green gypsiferous shale.
79.0	81.0	Red shale.
81.0	82.0	Green shale.
82.0	85.0	Brown gypsiferous shale.
85.0	89.0	Green gypsiferous shale.
89.0	90.0	Brown gypsiferous shale.
90.0	95.0	Green gypsiferous shale.
95.0	100.0	Red and brown shale.

Core Drill

100.0	101.7	Gypsum.
101.7	102.6	Greenish-brown gypsiferous shale.
102.6	123.2	Brown gypsiferous shale and shaley gypsum.
123.2	124.1	Reddish-brown mudstone.
124.1	125.0	Shaley gypsum.
125.0	126.5	Blue-gray mudstone.
126.5	128.5	Blue-gray gypsiferous mudstone.

Hole No. A-5 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
128.5	130.4	Reddish-brown gypsiferous mudstone.
130.4	130.8	Blue-gray mudstone.
130.8	135.1	Red shale.
135.1	135.5	Blue-green mudstone.
135.5	135.9	Blue-gray shale.
135.9	136.9	Red shale.
136.9	138.5	Variegated blue and brown shale.
138.5	140.0	Blue-gray shale.
140.0	142.8	Green mudstone.
142.8	158.7	Red shale.
158.7	163.0	Blue-green and blue-gray gypsiferous mudstone.
163.0	165.3	Brown, blue and gray gypsiferous mudstone.
165.3	165.6	Gray, dolomitic mudstone.
165.6	167.5	Blue-gray gypsiferous mudstone.
167.5	175.0	Red and gray silty shale.

Analysis, percent

No copper detected.

Buzzard Peak Area, King County, Texas
Ross Ranch

(Sec. 96, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-6

Drilling begun: January 5, 1969 Collar elevation (approximate):
Drilling completed: January 8, 1969 1650 feet above sea level

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay soil.
1.0	2.0	Brown clay.
2.0	3.0	Red clay.
3.0	4.0	Green shale.
4.0	7.0	Brown shale.
7.0	8.5	Green shale.
8.5	10.0	Gypsum.

Hole No. A-6 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
10.0	10.8	Gypsum.
10.8	11.8	Brownish-green and gray gypsiferous shale.
11.8	14.3	Reddish-brown clay shale.
14.3	15.0	Brown, green and gray gypsiferous shale.
15.0	18.4	Gypsum.
18.4	21.7	Blue, green, brown and gray clay shale.
21.7	29.0	Brown and red clayey shale.
29.0	31.4	Shaley gypsum.
31.4	31.8	Bluish-green clayey shale.
31.8	33.4	Variegated blue and brown clayey shale.
33.4	36.2	Red and brown clayey shale.
36.2	37.5	Variegated brown and bluish-green gypsiferous clayey shale.
37.5	40.0	Bluish-gray, gypsiferous siltstone.
40.0	42.2	Brown, gray and blue-gray siltstone, with selenite stringers.
42.2	49.0	Brown and red shale.
49.0	50.0	Blue-green gypsiferous shale.
50.0	50.3	Dolomite.
50.3	55.0	Brown and gray gypsiferous shale.
55.0	58.8	Blue-gray gypsiferous shale and shaley gypsum.
58.8	60.0	Blue and brown gypsiferous shale.
60.0	65.0	Red and blue, blue-green, and brown shale.
65.0	65.2	Red mudstone.
65.2	65.8	Blue-green gypsiferous siltstone.
65.8	70.0	Reddish-brown clayey shale.
70.0	73.0	Blue-gray, gypsiferous, clayey, siltstone.
73.0	80.0	Red clayey shale.
80.0	81.1	Red mudstone.
81.1	81.2	Blue-green gypsiferous shale.
81.2	81.3	Dolomite.
81.3	83.3	Blue-green gypsiferous shale and mudstone.
83.3	85.7	Red mudstone.
85.7	95.0	Red gypsiferous mudstone with blue and green streaks.
95.0	97.4	Blue-gray gypsiferous siltstone.
97.4	100.0	Blue-green and brown mudstone.
100.0	103.6	Alternating red shaley mudstone and blue-green, gypsiferous, sandstone.
103.6	105.0	Red shaley mudstone.
105.0	110.0	Greenish-gray cross-bedded, gypsiferous sandstone.
110.0	112.5	Reddish-brown and green cross-bedded sandstone and siltstone.

Hole No. A-6 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
112.5	130.9	Red and greenish-gray cross-bedded, gypsiferous sandstone with streaks of sandstone and conglomerate.
130.9	131.4	Green mudstone.
131.4	145.0	Red shale.
145.0	146.2	Brown and blue-green gypsiferous siltstone.
146.2	151.5	Brown silty shale.
151.5	154.5	Greenish-gray cross-bedded sandstone with shale streaks.
154.5	155.2	Greenish-gray shale.
155.2	157.1	Brown mudstone.
157.1	160.0	Alternating blue-green siltstone, and blue and brown shale.
160.0	175.3	Cross-bedded gypsiferous sandstone with mudstone and shale stringers.
175.3	180.0	Brown shale.
180.0	185.0	Red gypsiferous shale.
185.0	196.0	Red and brown mudstone with streaks of gypsum.
196.0	197.9	Variegated brown and green mudstone.
197.9	198.3	Dolomite.
198.3	198.9	Brown mudstone.
198.9	199.2	Dolomite.
199.2	201.0	Brown gypsiferous mudstone.

Analysis, percent

		Cu
40.3	40.6	.15
40.6	40.9	<.01
70.0	70.5	<.01
70.5	70.8	<.01
70.8	71.1	<.01
71.1	71.4	<.01
71.4	71.7	<.01
71.7	72.0	<.01
72.0	72.3	.04
72.3	72.6	<.01
170.5	171.0	.16
171.0	171.5	.05

(Sec. 2, J. G. Eustis Survey)

Hole No. A-7

Drilling begun: January 8, 1969 Collar elevation (approximate): 1650
Drilling completed: January 9, 1969 feet above sea level.

Rotary Drill

Depth, feet		
From-	To-	Formation
0	2.0	Brownish-black clay soil.
2.0	5.0	Brown clay.
5.0	7.0	Red clay.
7.0	9.0	Brown clay.
9.0	9.5	Dolomite.
9.5	10.0	Green shale.

Core Drill

10.0	14.0	Red clayey shale.
14.0	15.0	Brown clayey shale.
15.0	20.0	Green dolomitic shale with gypsum streaks.
20.0	21.6	Blue-green dolomitic, gypsiferous shale.
21.6	24.5	Brown, clayey, gypsiferous shale.
24.5	26.5	Clayey gypsum.
26.5	28.9	Blue-green and brown gypsiferous shale.
28.9	30.4	Gypsum.
30.4	31.9	Blue-green gypsiferous shale.
31.9	34.3	Red and brown shale with gypsum stringers.
34.3	38.7	Shaley gypsum.
38.7	41.7	Brown and green gypsiferous shale.
41.7	45.1	Gypsum.
45.1	46.5	Blue-green and brown gypsiferous shale.
46.5	50.0	Red gypsiferous shale.
50.0	55.0	Variegated brown and blue-green and brown, gypsiferous, clayey shale.
55.0	56.8	Gypsum.
56.8	60.0	Brown clayey shale.
60.0	61.1	Red shale.
61.1	65.3	Brown, blue, and green gypsiferous shale.
65.3	70.0	Brown shale.
70.0	72.2	Red shale.
72.2	73.0	Blue, green, and brown gypsiferous shale.
73.0	73.2	Dolomite.
73.2	75.0	Blue, green, and brown gypsiferous shale.
75.0	77.4	Brown mudstone.

Hole No. A-7 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
77.4	80.0	Shaley gypsum, and blue-green and brown gypsiferous shale.
80.0	85.0	Blue-green and reddish-brown gypsiferous mudstone.
85.0	88.6	Reddish-brown gypsiferous shale.
88.6	89.7	Blue-green gypsiferous siltstone.
89.7	94.3	Reddish-brown mudstone.
94.3	95.0	Blue-gray gypsiferous siltstone with gypsum and clay stringers.
95.0	100.0	Blue-green gypsiferous siltstone.
100.0	105.0	Red gypsiferous shale.

Analysis, percent

		Cu
97.0	97.5	<.01
97.5	98.0	<.01
98.0	98.5	<.01
98.5	99.0	<.01

Buzzard Peak Area, King County, Texas
6666 Ranch

(Sec. 112, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. A-8

Drilling begun: December 20, 1968
Drilling completed: December 21, 1968

Collar elevation (approximate): 1620 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay shale.
1.0	2.0	Brown gypsiferous clay.
2.0	4.0	Brown shale.
4.0	7.0	Brown and green gypsiferous shale.
7.0	10.0	Green shale.

Hole No. A-8 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
10.0	11.0	Brown shale.
11.0	16.0	Gypsum.
16.0	18.0	Green shaley gypsum.
18.0	19.0	Red shale.
19.0	21.0	Green shaley gypsum.
21.0	23.0	Gypsum.
23.0	26.0	Brown shale.
26.0	27.0	Brown and green shale.
27.0	30.0	Brown shale.
30.0	31.0	Green and brown shale.
31.0	32.0	Gray and brown shale.
32.0	35.0	Green gypsiferous shale.

Core Drill

35.0	45.0	Brown and green gypsiferous shale.
45.0	48.0	Brown shale.
48.0	53.0	Alternating blue, green, and brown shale, and gypsum.
53.0	54.2	Brown and green dolomitic shale.
54.2	59.1	Brown, blue, gray, and green dolomitic shale.
59.1	61.9	Brown shale.
61.9	62.1	Blue gypsiferous shale.
62.1	62.8	Blue-brown siltstone.
62.8	63.0	Brown gypsiferous shale.
63.0	73.0	Red gypsiferous shale.
73.0	75.3	Red and green mottled, gypsiferous shale.
75.3	78.8	Red shale.
78.8	79.0	Green shaley gypsum.

Analysis, percent

		Cu
54.0	54.3	.13
54.3	54.6	.04
54.6	54.9	<.01
54.9	55.2	<.01
55.2	55.7	<.01

Hole No. A-9

Drilling begun: December 19, 1968
Drilling completed: December 20, 1968

Collar elevation (approximate): 1605 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Red soil.
1.0	2.0	Green shaley gypsum.
2.0	3.0	Gypsum.
3.0	3.5	Green shale.
3.5	10.0	Brown shale.
		Core Drill
10.0	15.3	Brown and gray, clayey, gypsiferous shale.
15.3	19.8	Red shale.
19.8	25.4	Alternating gray, green, and red gypsiferous shale, and gypsum.
25.4	25.6	Dolomite.
25.6	26.2	Gray-green shale.
26.2	26.6	Dolomite.
26.6	27.1	Gray-green shale.
27.1	27.5	Dolomite.
27.5	29.3	Gray-green and brown shale.
29.3	38.8	Red, clayey, gypsiferous shale.
38.8	40.3	Red and green mottled shale.
40.3	40.5	Dolomite.
40.5	41.0	Greenish-gray, gypsiferous siltstone.
41.0	42.0	Green sandstone with gypsum stringers.
42.0	56.0	Green, brown, and red gypsiferous shale.
		Rotary Drill
56.0	57.0	Brown shale.
57.0	58.0	Brown and green shale.
58.0	61.0	Brown shale.
61.0	64.0	Brown gypsiferous shale.
64.0	71.0	Green shale.
71.0	73.0	Brown shale.
73.0	75.0	Green shale.
75.0	79.0	Green sandy shale.
79.0	89.0	Green, shaley, gypsiferous sandstone.

Hole No. A-9 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
89.0	95.0	Brown shale.
95.0	96.0	Brown shaley sandstone.
96.0	97.0	Brown shale.
97.0	98.0	Green shale.
98.0	99.0	Brown and green shale.
99.0	100.0	Green shale.
100.0	102.0	Green and brown shale.
102.0	103.0	Green shale.
103.0	104.0	Green and brown shale.
104.0	108.0	Green shale.
108.0	111.0	Green and brown shale.

Core Drill

111.0	111.2	Greenish-gray sandy shale.
111.2	111.4	Dolomite.
111.4	115.7	Green and brown gypsiferous shale.
115.7	121.8	Gray-green cross-bedded gypsiferous sandstone with clay streaks.
121.8	122.9	Blue, red, and brown shale and siltstone.
122.9	125.6	Blue-green sandstone with shale streaks.
125.6	128.0	Brown and red shale.
128.0	128.5	Blue-green sandy shale.
128.5	134.0	Blue-gray and brown gypsiferous cross-bedded sandstone.
134.0	134.2	Blue-gray gypsiferous shale.
134.2	137.2	Brown shale.
137.2	138.1	Brown siltstone and blue-green sandstone.
138.1	139.9	Blue-green, sandy, gypsiferous shale.
139.9	140.0	Gypsiferous sandstone.
140.0	141.6	Blue-gray gypsiferous shale, copper-bearing.
141.6	142.4	Brown shale and siltstone.
142.4	145.0	Blue-gray and red gypsiferous shale.

Analysis, percent

		Cu
140.0	140.3	7.01
140.3	140.6	7.01
140.6	140.9	7.01

(Sec. 256, Blk. F, Houston and Texas Central RR Co. Survey)

Hole No. B-1

Drilling begun: December 15, 1968
Drilling completed: December 15, 1968

Collar elevation (approximate): 1555 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay soil.
1.0	2.0	Brown clay.
2.0	3.0	Brown shale.
3.0	3.5	Gypsum.
3.5	4.0	Green shale.
4.0	6.0	Greenish-gray shale.
6.0	10.0	Brown shale.

Core Drill

10.0	26.8	Alternating brown, red, gray, and green gypsiferous, clayey shale.
26.8	27.1	Dolomite
27.1	28.0	Gray gypsiferous mudstone.
28.0	28.5	Shaley dolomite
28.5	29.5	Gray gypsiferous shale.
29.5	29.6	Dolomite.
29.6	30.0	Gray shale.
30.0	33.8	Blue shale.
33.8	35.2	Brown and blue gypsiferous shale.
35.2	41.3	Brown gypsiferous shale.
41.3	45.0	Blue-gray gypsiferous shale.
45.0	47.7	Brown shale.
47.7	49.1	Green gypsiferous shale.
49.1	50.0	Brown shale.

Analysis, percent

		Cu
26.8	27.1	.02
27.1	27.6	.03
27.6	28.1	.03
28.1	28.6	.03
28.6	29.1	.03
29:1	29.6	.06

Hole No. B-1 (cont'd)

Depth, feet		Analysis, percent (cont'd)
From-	To-	Cu
29.6	30.1	.04
30.1	30.6	.22
30.6	31.1	.14
31.1	31.6	.12
31.6	32.1	.09
32.1	32.6	.08
32.6	33.1	.13
33.1	33.6	.10

(Sec. 260, Blk. F, Houston and Texas Central RR Co. Survey)

Hole No. B-2

Drilling begun: December 12, 1968
Drilling completed: December 15, 1968

Collar elevation (approximate): 1621 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay soil.
1.0	3.0	Red clay.
3.0	4.0	Green clay.
4.0	5.0	Brown clay.
5.0	6.0	Red clay.
6.0	9.0	Green gypsiferous shale.
9.0	11.0	Gray shale.
11.0	11.5	Brown shale.
11.5	13.0	Gypsum.
13.0	15.5	Green shale.
15.5	16.0	Red shale.
16.0	18.5	Green and brown shale.

Hole No. B-2 (cont'd)

Core Drill

Depth, feet From-	To-	Formation
18.5	22.8	Gypsum.
22.8	23.5	Blue-green and brown shale.
23.5	25.6	Red shale.
25.6	31.5	Green and brown gypsiferous shale.
31.5	34.0	Blue and brown clayey shale.
34.0	38.9	Red gypsiferous shale.
38.9	39.2	Clayey gypsum.
39.2	47.0	Brown and gray gypsiferous shale.
47.0	50.9	Red shale.
50.9	52.8	Brown and red shale and shaley gypsum.
52.8	55.0	Red shale.
55.0	56.8	Brown, blue, and red shale and gypsum.
56.8	59.0	Blue-green shale.
59.0	60.0	Brown and blue shale.
60.0	63.4	Brown, green, and gray gypsiferous shale.
63.4	65.4	Gray, shaley sandstone.
65.4	70.0	Red and blue gypsiferous shale.

Rotary Drill

70.0	73.0	Brown shale.
73.0	75.0	Green gypsiferous shale.
75.0	77.0	Brown shale.
77.0	80.0	Green shale.
80.0	86.0	Brown shale.
86.0	89.0	Green shale.
89.0	93.0	Brown gypsiferous shale.
93.0	95.0	Green shale.
95.0	101.0	Brown shale.
101.0	103.0	Green shale.
103.0	108.5	Brown shale.
108.5	110.5	Green shale.
110.5	111.0	Red and gray sandstone.
111.0	114.0	Green gypsiferous shale.
114.0	116.0	Green gypsiferous sandstone.
116.0	120.0	Green gypsiferous sandy shale.
120.0	121.0	Red shale.
121.0	122.0	Green and brown gypsiferous shale.
122.0	123.0	Red shale.
123.0	125.0	Green shale.
125.0	128.5	Brown gypsiferous sandstone.

Hole No. B-2 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
128.5	133.7	Gray and brown cross-bedded, shaley sandstone.
133.7	136.0	Red shale.
136.0	136.8	Red and green gypsiferous shale.
136.8	142.8	Red shale.
142.8	144.5	Brown and gray, and blue-gray shale and siltstone.
144.5	146.6	Red shale.
146.6	146.9	Blue gypsiferous shale.
146.9	147.2	Cross-bedded sandstone.
147.2	148.1	Green, brown, and red shale.
148.1	149.2	Blue-gray sandstone.
149.2	149.7	Reddish-brown and gray shale.
149.7	153.0	Greenish-gray cross-bedded sandstone.
153.0	165.0	Alternating red and brown shale, and gray and brown sandstone.
165.0	167.0	Gray cross-bedded sandstone.
167.0	171.0	Green and gray gypsiferous sandstone, and brown and green shale.
171.0	176.0	Alternating green gypsiferous shale, and green gypsiferous, cross-bedded sandstone.
176.0	180.5	Alternating red-green gypsiferous shale, and green-brown sandstone and siltstone.
180.5	186.5	Red shale.

Analysis, percent

No copper detected.

(Sec. 86, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. B-3

Drilling begun:	December 9, 1968	Collar elevation (approximate):
Drilling completed:	December 11, 1968	1631 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay soil.
1.0	6.0	Red and green gypsiferous shale.
6.0	9.0	Green shale.
9.0	10.0	Gypsiferous clayey shale.

Hole No. B-3 (cont'd)

Core Drill

Depth, feet From-	To-	Formation
10.0	11.5	Brown and blue clayey shale.
11.5	11.8	Dolomite.
11.8	15.0	Blue-gray, brown and red, gypsiferous shale.
15.0	20.1	Gypsum.
20.1	21.9	Blue shale.
21.9	22.1	Brown and blue clay.
22.1	29.5	Red clayey shale.
29.5	30.0	Blue gypsiferous shale.
30.0	39.8	Alternating blue-green and brown gypsiferous shale, and clayey gypsum.
39.8	40.4	Clayey gypsum, copper bearing.
40.4	45.0	Greenish-gray and reddish-brown gypsiferous shale.
45.0	46.8	Red shale.
46.8	50.0	Green, gray, and reddish-brown gypsiferous shale.
50.0	55.0	Reddish-brown, brown and green gypsiferous shale.
55.0	60.0	Blue, green, and red gypsiferous shale.
60.0	65.0	Shaley gypsum and red gypsiferous shale.
65.0	68.9	Blue, red, and green gypsiferous shale.
68.9	70.8	Blue and green sandy shale.
70.8	81.2	Red and green gypsiferous shale.
81.2	86.5	Red gypsiferous shale.
86.5	88.0	Green shale.
88.0	90.3	Gray gypsiferous sandstone.
90.3	100.0	Gray-green and red gypsiferous, sandy shale with sandstone streaks.
100.0	105.0	Gray gypsiferous sandstone.
105.0	110.0	Blue-gray, brown and green gypsiferous shale.
110.0	117.5	Blue-gray, clayey, gypsiferous sandstone.
117.5	128.0	Red gypsiferous shale.
128.0	128.7	Blue-green and brown shale.
128.7	133.1	Blue-gray, clayey, gypsiferous sandstone.
133.1	133.7	Blue-green shale.
133.7	136.0	Red shale.
136.0	136.3	Green shale.
136.3	140.0	Red shale.
140.0	140.3	Variegated brown and green shale.
140.3	143.4	Red shale.
143.4	144.2	Blue shale.
144.2	146.9	Red shale.
146.9	150.0	Alternating green, red and gray gypsiferous shale and greenish-gray gypsiferous sandstone.

Hole No. B-3 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
150.0	153.2	Brown and green gypsiferous shale.
153.2	155.0	Brown clayey sandstone.
155.0	157.5	Red shale.
157.5	160.0	Greenish-gray and variegated green and brown shale.
160.0	161.3	Variegated brown and green siltstone.
161.3	164.3	Green and greenish-gray cross-bedded sandstone.
164.3	164.5	Interlayered gypsum and green siltstone.
164.5	165.0	Variegated green and brown siltstone.
165.0	170.0	Alternating red, gray, and green gypsiferous sandstone, and red, gray, and brown gypsiferous shale.

Analysis, percent

		Cu
39.8	40.2	.09
40.4	40.9	.09
163.9	164.1	.01
164.1	164.4	.10
164.4	164.7	.70

Buzzard Peak Area, King County, Texas
Hardwick Ranch

(Sec. 89, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-1

Drilling begun: November 24, 1968 Collar elevation (approximate):
Drilling completed: November 24, 1968 1540 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	5.0	Soil and brown clay.
5.0	7.0	Brown shale.
7.0	8.0	Green shale.
8.0	9.0	Red shale.

Hole No. C-1 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
9.0	10.0	Gray shale.
10.0	12.0	Sandy gray shale.
12.0	15.0	Gray sandstone.
15.0	16.0	Red shale.
16.0	18.0	Red shale.
18.0	25.0	Red shale.
25.0	28.0	Gray shale.
28.0	31.0	Red shale.
31.0	33.0	Green shale.
33.0	37.0	Red shale.
37.0	39.0	Brown shale.
39.0	52.0	Red gypsiferous shale.
52.0	55.0	Brown and gray shale.

Core Drill

55.0	60.0	No core recovered.

Analysis, percent

No copper detected.

Buzzard Peak Area, King County, Texas
Hendrix Ranch

(Sec. 90, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-2

Drilling begun:	November 25, 1968	Collar elevation (approximate):
Drilling completed:	November 25, 1968	1580 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Brown soil.
.2.0	10.0	Red shale.
10.0	11.0	Gray shale.
11.0	12.0	Gray and red shale.

Hole No. C-2 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
12.0	14.0	Gray shale.
14.0	21.0	Green shale.
21.0	23.0	Red and green sandy shale.
23.0	25.0	Red sandstone.
25.0	30.0	Red and green shale.
30.0	34.0	Gray sandstone.
34.0	35.0	Gray sandstone and shale.
35.0	39.0	Gray sandstone.
39.0	42.0	Green sandy shale.
42.0	50.0	Red shale.
50.0	53.0	Sandstone.

Core Drill

53.0	53.7	Green cross-bedded sandstone.
53.7	54.2	Green sandy shale.
54.2	55.9	Red and green shale.
55.9	56.3	Gray sandstone.
56.3	64.0	Red, green, and brown gypsiferous shale.
64.0	71.5	Brown gypsiferous shale.
71.5	74.2	Red shale.
74.2	74.3	Green sandstone.
74.3	78.2	Sandstone with little green and brown shale.
78.2	79.5	Brown shale.

Analysis, percent

No copper detected.

(Sec. 87, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-3

Drilling begun: December 7, 1968
Drilling completed: December 7, 1968

Collar elevation (approximate): 1585 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	3.0	Red soil and red clay.
3.0	4.0	Brown soil and brown clay.
4.0	5.0	Gray clay.
5.0	7.0	Green clay.
7.0	9.0	Red clay.
9.0	14.0	Red shale.
14.0	16.0	Brown shale.
16.0	17.0	Gray clay.
17.0	19.0	Brownish-gray shale.
19.0	20.0	Gray sandstone.
20.0	24.0	White sandstone.
24.0	29.5	Green sandstone.
29.5	34.5	Red shale.
34.5	35.0	Gray shale and sandstone.
35.0	36.5	Green shale.
36.5	41.0	Red shale.
41.0	42.0	Brown shale.
42.0	44.0	Green shale.
44.0	52.0	Brown and green siltstone.
52.0	57.0	Brown sandy shale.

Core Drill

57.0	64.0	Red shale.
64.0	66.0	Green sandstone.
66.0	67.2	Red and green shale.
67.2	67.7	Greenish-gray sandstone.
67.7	70.8	Red and gray gypsiferous shale.
70.8	71.1	Red and gray mudstone.
71.1	74.9	Gray cross-bedded, gypsiferous sandstone.
74.9	78.0	Blue gypsiferous shale--bottom in red shale.

Analysis, percent

		Cu
74.4	74.7	.59
74.7	75.0	.05

(Sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-4

Drilling begun:	December 8, 1968	Collar elevation (approximate):
Drilling completed:	December 8, 1968	1580 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Brown clay soil.
2.0	10.0	Brown clay shale.
10.0	13.0	Green shale.
13.0	14.0	Brown sandy shale.
14.0	20.0	Green sandy shale with sandstone stringers.
20.0	22.0	Red shale.
22.0	23.0	Red and green shale.
23.0	24.0	Red shale.
24.0	27.0	Gray sandstone.
27.0	31.0	Green sandstone.
31.0	32.0	Green shale.
32.0	36.0	Red shale.
36.0	42.0	Green sandy shale.
42.0	44.0	Red shale.
44.0	45.0	Green sandy shale.
45.0	46.0	Red shale.
46.0	49.0	Gray sandstone.
49.0	56.0	Green shale and soft sandstone.
56.0	58.0	Brown and green shale.
58.0	60.0	Red shale.
60.0	61.0	Green shale.
61.0	61.5	Sandstone.

Core Drill

61.5	62.5	Gray-green, cross-bedded sandstone.
62.5	63.2	Green sandy shale.
63.2	64.9	Red shale.
64.9	66.5	Green gypsiferous shale.

Analysis, percent

		Cu
62.4	62.7	.05
62.7	63.0	.04

Hole No. C-5

Drilling begun: December 7, 1968
Drilling completed: December 8, 1969

Collar elevation (approximate): 1595 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	4.0	Brown-black clay soil.
4.0	5.0	Red clay.
5.0	9.0	Green, sandy, gypsiferous shale.
9.0	10.0	Red shale.
10.0	12.0	Green siltstone.
12.0	16.0	Red and green sandstone.
16.0	18.0	Green sandy shale.
18.0	27.0	Red shale.
27.0	30.0	Green sandy shale.
30.0	39.0	Greenish gray sandstone.
39.0	43.0	Red shale.
43.0	44.0	Red and green shale.
44.0	47.0	Red shale.
47.0	48.0	Red and green shale.
48.0	50.0	Green sandy shale.
50.0	53.0	Red and green shale.

Core Drill

53.0	53.4	Greenish-gray cross-bedded sandstone.
53.4	54.0	Greenish-gray gypsiferous shale.
54.0	60.2	Gray cross-bedded sandstone.
60.2	60.5	Gray-green gypsiferous shale.
60.5	61.6	Red shale.
61.6	63.3	Gray-green sandy shale.
63.3	64.8	Greenish-gray shale.
64.8	66.0	Red sandy shale.

Rotary Drill

66.0	68.0	Brown shale.
68.0	69.0	Brown and green shale.
69.0	70.0	Green shale.
70.0	83.0	Green and brown shale.
83.0	86.0	Red shale.
86.0	98.0	Brown gypsiferous shale.

Hole No. C-5 (cont'd)

Analysis, percent

No copper detected.

Buzzard Peak Area, Knox County, Texas
McFaddin Ranch

(Sec. 30, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-6

Drilling begun: November 21, 1968
Drilling completed: November 22, 1968

Collar elevation (approximate): 1580 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Clay soil.
1.0	3.0	Red shale.
3.0	4.0	Gray shale.
4.0	9.0	Red shale.
9.0	10.0	Gray shale.
10.0	12.0	Red shale.
12.0	13.0	Gray shale.
13.0	14.0	Gray and green sandstone.
14.0	15.0	Brown shale.
15.0	17.0	Gray shale.
17.0	22.0	Gray sandstone.

Core Drill

22.0	27.0	Green, soft sandstone.
27.0	27.2	Green shale.
27.2	28.7	Red shale.
28.7	29.0	Greenish-gray cross-bedded sandstone.
29.0	30.1	Blue, gray, and red gypsiferous shale.
30.1	30.4	Gray sandstone.
30.4	36.0	Red shale with layers of sandstone.
36.0	36.3	Gray sandy shale.
36.3	39.4	Greenish-gray cross-bedded sandstone.
39.4	41.8	Green sandy shale.
41.8	43.9	Red shale.
43.9	45.0	Green shale.
45.0	45.9	Blue-green shale.
45.9	47.0	Brown shale.

Hole No. C-6 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
44.7	45.0	.03
45.3	45.6	.23
45.6	45.9	.04

(Sec. 31, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-7

Drilling begun: November 22, 1968
Drilling completed: November 23, 1968
Collar elevation (approximate): 1575 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	3.0	Red and green clay.
3.0	4.0	Green clay.
4.0	5.0	Green shale.
5.0	9.0	Red shale.
9.0	10.0	Red and gray shale.
10.0	11.0	Red shale.
11.0	12.0	Green shale.
12.0	22.0	Red shale.
22.0	22.5	Green shale.
22.5	24.0	Gray sandstone.

Core Drill

24.0	24.4	Gray sandstone.
24.4	24.6	Dolomite.
24.6	24.8	Green shale.
24.8	25.0	Green silty dolomite.
25.0	27.7	Red and green shale.
27.7	31.6	Gray sandstone.
31.6	34.5	Alternating green and red shale, and gray sandstone.
34.5	36.0	Red shale.

Hole No. C-7 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
36.0	37.0	Red shale.
37.0	39.0	Red and green shale.
39.0	53.0	Green shale and interbedded sandstone.
53.0	54.0	Red and green shale.
54.0	55.0	Green shale.
55.0	56.0	Red shale and gray sandstone.
56.0	58.0	Red and green shale.

Analysis, percent

No copper detected.

(Sec. 30, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-8

Drilling begun: November 20, 1968
Drilling completed: November 21, 1968
Collar elevation (approximate): 1575 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	12.5	Red and gray sandy clay.

Core Drill

12.5	13.8	Gray sandstone.
13.8	21.0	Red shale.
21.0	22.0	Green shale.
22.0	22.7	Green sandstone.
22.7	23.3	Green shale.
23.3	24.5	Greenish-gray cross-bedded sandstone.
24.5	26.5	Green shale.
26.5	31.0	Red shale.

Analysis, percent

		Cu
24.5	25.0	.16
25.0	25.3	.58
25.3	25.6	.07

(Sec. 74, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-9

Drilling begun: November 23, 1968
Drilling completed: November 23, 1968

Collar elevation (approximate): 1599 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Brown soil.
2.0	3.0	Gray shale.
3.0	4.0	Gypsum.
4.0	5.0	Gray shale.
5.0	6.0	Gray sandstone.
6.0	7.0	Red shale.
7.0	9.0	Red shale and limestone.
9.0	10.0	Red sandy shale.
10.0	13.0	Red sandstone.
13.0	14.0	Green shaley sandstone.
14.0	15.0	Green shale.
15.0	19.0	Red shale.
19.0	21.0	Green shale.
21.0	23.0	Red and green shale.
23.0	27.0	Green shale.
27.0	37.0	Red shale.
37.0	39.0	Green shale.
39.0	44.0	Red shale.
44.0	45.0	Red and green shale.
45.0	46.0	Gray shale and sandstone.
46.0	47.0	Gray sandstone.
47.0	53.0	Gray shaley sandstone.

Core Drill

53.0	55.1	Gray sandstone.
55.1	57.2	Red and green shale.
57.2	59.5	Gray sandstone.
59.5	61.0	Green shale.
61.0	63.0	Greenish-gray, red, and brown sandy shale.
63.0	66.5	Red shale, shaley sandstone, and red sandstone.
66.5	70.0	Red shale.
70.0	73.3	Brown and red shale.
73.3	74.2	Gypsum.
74.2	74.7	Red shale.
74.7	75.0	Dolomite.
75.0	76.5	Red gypsiferous shale.

Hole No. C-9 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
59.9	60.2	.19
60.2	60.5	.28

(Sec. 32, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-10

Drilling begun: November 22, 1968
Drilling completed: November 22, 1968

Collar elevation (approximate): 1553 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	6.5	Red clay.
6.5	8.0	Green clay.
8.0	9.0	Red shale.
9.0	10.0	Red and green shale.
10.0	11.0	Red shale.
11.0	12.5	Green sandstone.
12.5	15.0	Green shale.
15.0	16.0	Green sandstone.
16.0	20.5	Green shale and sandstone.
20.5	22.0	Brown and red shale.
22.0	24.0	Red and green shale.
24.0	29.5	Green shale.
29.5	30.0	Red shale.

Core Drill

30.0	33.2	Greenish-gray cross-bedded sandstone.
33.2	33.9	Green shale.
33.9	36.5	Red gypsiferous, sandy shale.

Analysis, percent

		Cu
32.8	33.3	.05
33.3	33.8	.10
33.8	34.1	.50
34.1	34.4	.04

(Sec. 31, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-11

Drilling begun: November 23, 1968
Drilling completed: November 23, 1968

Collar elevation (approximate): 1568 feet above sea level.

Rotary Drill

Depth, feet		Formation
From–	To–	
0	10.0	Red and green shale.
10.0	12.0	Green shale.
12.0	13.0	Gray sandstone and green shale.
13.0	15.0	Gray shale.
15.0	17.0	Green shale.
17.0	33.0	Red shale.

Core Drill

33.0	34.3	Gray sandstone with dolomite stringers.
34.3	35.3	Gray sandy shale.
35.3	36.8	Gray sandstone and blue and red shale.
36.8	39.0	Shaley sandstone (water).
39.0	39.9	Red shale.
39.9	42.1	Gray, cross-bedded sandstone.
42.1	45.7	Alternating layers of green gypsiferous shale and gray sandstone.
45.7	48.2	Red and green shale.
48.2	50.0	Green shaley sandstone.
50.0	52.9	Green, red, and brown shale.
52.9	54.2	Green sandy shale.
54.2	56.0	Red shale.

Analysis, percent

No copper detected.

Buzzard Peak Area, King County, Texas
Hendrix Ranch

(Sec. 87, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-12-B

Drilling begun: December 5, 1968
Drilling completed: December 6, 1968

Collar elevation (approximate): 1575 feet above sea level.

Rotary Drill

Depth, feet From-	To-	Formation
0	1.0	Red soil.
1.0	2.0	Brown soil.
2.0	4.0	Brown clay.
4.0	19.0	Red shale.
19.0	20.0	Blue shale.
20.0	28.0	Sandstone.
28.0	30.0	Red shale.
30.0	31.0	Green sandy, gypsiferous shale.
31.0	33.0	Red sandy clay.
33.0	38.0	Sandstone.
38.0	38.5	Green shale.
38.5	43.0	Red shale.
43.0	44.0	Green sandy shale.
44.0	45.0	Red shale.
45.0	47.0	Green and gray sandy shale.
47.0	49.0	Green sandstone.
49.0	52.0	Red shale.
52.0	53.0	Green shale.
53.0	56.0	Red shale.

Core Drill

56.0	69.0	Greenish-gray gypsiferous sandstone.
69.0	69.9	Green shale.
69.9	73.0	Brown shale.
73.0	73.8	Green sandy shale.
73.8	75.9	Gray, cross-bedded, gypsiferous sandstone.
75.9	87.5	Gray, red, and green gypsiferous silty shale.

Analysis, percent

No copper detected.

Buzzard Peak Area, King County, Texas
Hardwick Ranch

(Sec. 89, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-13

Drilling begun: November 25, 1968
Drilling completed: December 5, 1968

Collar elevation (approximate): 1553 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	3.0	Brown soil and clay.
3.0	13.0	Brown clay shale.
13.0	19.0	Brown, gypsiferous clay shale.
19.0	23.0	Red shale.
23.0	24.0	Red shale and sandstone.
24.0	25.0	Green shale.

Core Drill

25.0	30.8	Green, gypsiferous shale.
30.8	36.5	Red shale.
36.5	37.3	Green and red gypsiferous shale.
37.3	46.0	Red gypsiferous shale.
46.0	46.4	Dolomitic siltstone.
46.4	52.7	Gray and brown gypsiferous shale.
52.7	54.4	Blue-green gypsiferous shale.
54.4	56.6	Brown shale.
56.6	56.8	Dolomite.
56.8	58.0	Brown and green shale.

Analysis, percent

No copper detected.

Buzzard Peak Area, King County, Texas
Hendrix Ranch

(Sec. 82, Blk. 13, Houston and Texas Central RR Co. Survey)

Hole No. C-14

Drilling begun: December 9, 1968
Drilling completed: December 9, 1968

Collar elevation (approximate): 1525 feet above sea level.

Rotary Drill

Depth, feet From-	To-	Formation
0	5.5	Gray-green sandstone.
5.5	7.5	Red shale.
7.5	8.0	Sandstone.
8.0	10.0	Blue-green and red shale.

Core Drill

From-	To-	Formation
10.0	13.0	Green shale.
13.0	15.0	Red shale.
15.0	16.0	Green shale.
16.0	20.0	Red shale.
20.0	20.5	Blue-green shale.
20.5	27.5	Gray, cross-bedded sandstone.

Analysis, percent

From-	To-	Cu
23.5	24.0	.05
24.0	24.3	.10
24.3	24.6	.40
24.6	24.9	.04

Buzzard Peak Area, King County, Texas
6666 Ranch

(Sec. 261, Blk. F, Houston and Texas Central RR Co. Survey)

Hole No. C-15

Drilling begun:	December 11, 1968	Collar elevation (approximate):
Drilling completed:	December 12, 1968	1535 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	1.0	Brown clay soil.
1.0	2.0	Brown clay.
2.0	7.0	Red clay.
7.0	8.0	Red clay and caliche.
8.0	13.0	Clayey dolomite.
13.0	17.0	Red shale and siltstone.
17.0	19.0	Red shale and dolomite.
19.0	23.0	Red, blue, gray, and green shale.
23.0	25.0	Red and green shale.
25.0	26.0	Red shale.
26.0	29.0	Red and green shale with dolomite stringers.

Core Drill

29.0	32.1	Reddish-brown gypsiferous sandstone.
32.1	36.0	Gray and greenish gray, gypsiferous sandstone.
36.0	36.9	Green, gray,and brown shale with sandstone stringers.
36.9	40.2	Gray-green gypsiferous sandstone.
40.2	47.4	Blue-green, brown, and red gypsiferous shale and siltstone.
47.4	50.0	Green gypsiferous clay.
50.0	59.0	Red, blue, green, and brown gypsiferous shale.

Analysis, percent

		Cu
48.5	48.8	.10
48.8	49.1	.10
49.1	49.4	.12
49.4	49.7	.10
49.7	50.0	.28

Truscott Area, Knox County, Texas
Alexander Ranch

(Sec. 26, Blk. 4, Dallas and Wichita RR Co. Survey)

Hole No. D-1

Drilling begun: November 19, 1968
Drilling completed: November 20, 1968
Collar elevation (approximate): 1620 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	15.0	Alternating red and gray shale.

Core Drill

From-	To-	Formation
15.0	15.8	Gray-brown shale.
15.8	17.5	Brownish-gray clay.
17.5	23.0	Red clay with gray streaks.
23.0	23.3	Variegated brown and gray shale.
23.3	25.4	Gypsum.
25.4	26.0	Variegated brown and green shale.
26.0	27.3	Red shale.
27.3	27.8	Greenish gypsiferous sandstone.
27.8	29.0	Red clay.
29.0	50.0	Alternating green, brown, and red gypsiferous clay.

Analysis, percent

No copper detected.

Hole No. D-2

Drilling begun: November 20, 1968
Drilling completed: November 20, 1968
Collar elevation (approximate): 1600 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	6.0	Red clay.
6.0	10.0	Red clay and gypsum.
10.0	16.0	Red and brown clay.
16.0	21.0	Gypsum.

Hole No. D-2 (cont'd)

Rotary Drill

Depth, feet		Formation
From-	To-	
21.0	23.0	Gray shale.
23.0	25.0	Red and green gypsiferous shale.
25.0	27.0	Brown shale.
27.0	29.0	Gray shale.
29.0	36.5	Brown gypsiferous shale.
36.5	37.0	Green shale.
37.0	38.0	Red shale.
38.0	39.0	Gray shale.
39.0	44.0	Brown shale.
44.0	50.0	Alternating brown and gray shale.

Analysis, percent

No copper detected.

Medicine Mound Area, Hardeman County, Texas
Brown Ranch

(NW 1/4 sec. 62, Blk. H, Waco and Northwestern RR Co. Survey)

Hole No. E-1

Drilling begun: November 16, 1968 Collar elevation (approximate):
Drilling completed: November 16, 1968 1570 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	2.0	Gypsum.
2.0	4.0	Blue clay.
4.0	6.0	Brown clay.
6.0	8.0	Gypsum.
8.0	11.5	Gray clay.
11.5	13.0	Gypsum.
13.0	18.0	Alternating beds of red and gray clay.
18.0	21.0	Gypsum.
21.0	25.0	Alternating beds of blue-green and red shale with selenite stringers.

Hole No. E-1 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
25.0	27.2	Red shale.
27.2	27.7	Dolomite
27.7	29.5	Red and gray shale.
29.5	30.0	Dolomite and blue shale.
30.0	40.0	Alternating red, gray, and brown shale with thin gypsum stringers.
40.0	41.7	Variegated brown, green, and gray shale.
41.7	42.9	Alternating thin layers of dolomite, and gray and blue gypsiferous shale.
42.9	44.1	Blue and blue-green gypsiferous shale--copper bearing.
44.1	45.0	Red gypsiferous shale.
45.0	46.2	Variegated brown and green gypsiferous shale.
46.2	49.3	Gypsum.
49.3	50.8	Cross-bedded siltstone.
50.8	51.0	Red shale.

Analysis, percent

		Cu
42.9	43.2	.38
43.2	43.5	.46
43.5	43.8	1.50
43.8	44.1	.27
49.3	49.8	.04

(NE 1/4 sec. 86, Blk. H, Waco and Northwestern RR Co. Survey)

Hole No. E-2

Drilling begun: November 11, 1968
Drilling completed: November 12, 1968

Collar elevation (approximate): 1550 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	13.0	Alternating red clay and gray gypsiferous shale.

Hole No. E-2 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
13.0	16.0	Blue-gray gypsiferous shale.
16.0	16.5	Gypsum.
16.5	18.9	Green gypsiferous shale.
18.9	20.4	Red shale.
20.4	23.3	Gray gypsiferous shale with yellow streaks.
23.3	25.1	Red gypsiferous shale.
25.1	30.5	Gypsum.
30.5	31.0	Blue shale.
31.0	33.0	Red shale.
33.0	35.5	Gray shale.
35.5	40.5	Gypsum with red shale layers.
40.5	41.0	Blue shale.
41.0	43.0	Variegated blue and red shale.
43.0	53.0	Red clayey shale with selenite stringers.

Analysis, percent

No copper detected.

(NE 1/4 SW 1/4 sec. 86, Blk. H, Waco and Northwestern RR Co. Survey)

Hole No. E-3

Drilling begun: November 13, 1968
Drilling completed: November 14, 1968

Collar elevation (approximate): 1550 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	0.5	Red clayey soil.
0.5	10.0	Weathered dolomite and gray shale.

Hole No. E-3 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
10.0	10.3	Gypsum.
10.3	15.0	Gray gypsiferous shale.
15.0	16.5	Gypsum.
16.5	17.9	Gray shale.
17.9	18.5	Gypsum.
18.5	19.0	Gypsiferous shale.
19.0	20.5	Alternating layers of gypsum, and greenish-gray and brown shale.
20.5	24.5	Gypsum.
24.5	30.0	Blue-gray to dark gray gypsiferous shale.
30.0	32.5	Red clay with gypsum stringers.
32.5	34.0	Gray gypsiferous shale.
34.0	35.0	Red clay.
35.0	35.5	Blue-gray shale.
35.5	35.9	Dolomite.
35.9	37.1	Red clay.
37.1	38.3	Gypsum.
38.3	41.5	Blue-gray shale.
41.5	43.7	Gypsum.
43.7	47.0	Blue-gray shale.
47.0	51.5	Alternating green and brown variegated shale, greenish-gray shale, and gray-brown with gypsum stringers.
51.5	53.8	Brown clay with gypsum stringers.
53.8	58.7	Gypsum.
58.7	58.8	Dolomite.
58.8	60.0	Blue shale.

Analysis, percent

		Cu
58.8	59.1	.04
59.1	59.4	.02
59.4	59.7	.03

(SW 1/4 sec. 86, Blk. H, Waco and Northwestern RR Co. Survey)

Hole No. E-4

Drilling begun: November 12, 1968
Drilling completed: November 13, 1968

Collar elevation (approximate): 1565 feet above sea level.

Rotary Drill

Depth, feet From-	To-	Formation
0	0.5	Soil.
0.5	5.0	Gypsum.
5.0	10.0	Alternating gray dolomite, shale, and gypsum.

Core Drill

From-	To-	Formation
10.0	15.0	Blue shale with gypsum stringers.
15.0	15.4	Gypsum.
15.4	16.4	Blue-gray gypsiferous shale.
16.4	19.4	Reddish-brown clayey shale.
19.4	23.0	Gray gypsiferous shale.
23.0	24.3	Blue-gray gypsiferous shale.
24.3	26.2	Gypsum.
26.2	27.8	Gray gypsiferous shale.
27.8	28.5	Red clay.
28.5	30.0	Gypsum.
30.0	34.5	Blue shale with gypsum stringers.
34.5	37.0	Red gypsiferous clay.
37.0	41.9	Brown and gray variegated clay.
41.9	42.3	Dolomite.
42.3	48.0	Gray gypsiferous shale with gypsum stringers.
48.0	50.7	Gypsum.
50.7	52.2	Blue shale.
52.2	53.7	Gray gypsiferous shale.
53.7	55.6	Reddish-brown gypsiferous shale.
55.6	58.4	Gray shale with gypsum stringers.
58.4	59.4	Red gypsiferous shale.
59.4	64.6	Gypsum.
64.6	64.8	Dolomite, copper bearing.
64.8	66.1	Gray shale, copper bearing.
66.1	67.4	Red shale with gypsum stringers.
67.4	69.5	Red and gray mottled shale.
69.5	70.8	Gray silty shale.
70.8	74.5	Brown and gray clay with gypsum stringers.

Hole No. E-4 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
64.6	64.8	.16
64.8	65.1	.65
65.1	65.4	.40
65.4	65.7	.16

(Center North Line sec. 9, E.L. and R.R. RR Co. Survey)

Hole No. E-5

Drilling begun: November 14, 1968
Drilling completed: November 16, 1968

Collar elevation (approximate): 1550 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	10.0	No samples recovered.

Core Drill

10.0	14.5	Shale.
14.5	17.4	Gypsum.
17.4	19.0	Gray shale.
19.0	22.0	Blue shale.
22.0	26.4	Brown shale with gypsum stringers.
26.4	30.0	Gray shale with gypsum stringers.
30.0	33.6	Blue-gray shale with gypsum stringers.
33.6	36.0	Brown and gray shale.
36.0	36.3	Siltstone.
36.3	36.7	Dolomite.
36.7	40.8	Gypsum.
40.8	44.3	Gray shale.
44.3	49.0	Alternating red and brown clay and gypsum.
49.0	49.7	Gypsum.
49.7	51.1	Blue gypsiferous shale.
51.1	53.8	Red and gray variegated shale with gypsum stringers.
53.8	54.0	Blue shale.

Hole No. E-5 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
43.4	43.7	.82
43.7	44.1	.07
49.5	49.8	.20

Medicine Mound Area, Hardeman County, Texas
Williams Ranch

(Hopkins County School Land, A-14)

Hole No. E-6

Drilling begun: November 17, 1968
Drilling completed: November 17, 1968
Collar elevation (approximate): 1550 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	10.0	Soil, weathered gypsum and red clay.

Core Drill

10.0	14.2	Red and gray shale with gypsum stringers.
14.2	15.0	Blue and gray shale with gypsum stringers.
15.0	15.7	Gray silty mudstone.
15.7	16.6	Gray shale and dolomite.
16.6	22.7	Alternating red and blue-gray shale, and gypsum.
22.7	24.8	Gypsum.
24.8	28.6	Blue-gray shale with gypsum stringers.
28.6	29.7	Red shale.
29.7	31.0	Blue-gray shale.
31.0	31.3	Gray siltstone.
31.3	32.5	Blue gypsiferous shale.
32.5	38.0	Gypsum with mottled blue and gray shale.
38.0	38.1	Dolomite.
38.1	39.5	Gray-green gypsiferous shale--copper-bearing.
39.5	43.0	Brown to red shale.

Hole No. E-6 (cont'd)

Depth, feet		Analysis, percent
From-	To-	Cu
38.0	38.3	.14
38.3	38.6	1.25
38.6	38.9	.65

Hole No. E-7

Drilling begun: November 17, 1968 Collar elevation (approximate):
Drilling completed: November 17, 1968 1550 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	14.0	Soil, weathered gypsum and clay.
14.0	19.0	Red and gray gypsiferous clay.
19.0	24.0	Blue-gray gypsiferous clay.
24.0	25.0	Silty mudstone.
25.0	26.0	Gray shale.
26.0	32.0	Alternating red and blue shale and gypsum.
32.0	34.0	Gypsum.
34.0	39.0	Blue-gray and red shale with gypsum stringers.
39.0	40.0	Blue-gray shale.
40.0	41.0	Blue gypsiferous shale.
41.0	46.0	Gypsum.

Core Drill

46.0	47.4	Gypsum.
47.4	47.6	Dolomite.
47.6	49.7	Blue-gray shale.
49.7	51.0	Red shale.

Analysis, Percent

		Cu
47.3	47.6	.07
47.6	47.9	.15
47.9	48.2	.36

Medicine Mound Area, Hardeman County, Texas
Holcomb Ranch

(SW 1/4 sec. 101, Blk. H, Waco and Northwestern RR Co. Survey)

Hole No. E-8

Drilling begun: November 18, 1968
Drilling completed: November 18, 1968

Collar elevation (approximate): 1565 feet above sea level.

Rotary Drill

Depth, feet		Formation
From-	To-	
0	48.0	Red soil and red clay, and red, blue, and green shale.
48.0	55.0	Shale with thin layers of dolomite.
55.0	60.0	Gray shale.
60.0	70.0	Red and gray shale.
70.0	71.0	Gray shale and dolomite.
71.0	78.0	Red and gray shale.
78.0	83.0	Blue shale.
83.0	85.0	Red shale with gypsum stringers.
85.0	98.0	Gray-green shale with gypsum stringers.
98.0	100.0	Gray shale with thin gypsum and dolomite stringers.
100.0	105.0	Red gypsiferous shale.
105.0	107.0	Brown and gray gypsiferous shale.
107.0	121.0	Gypsum hard to medium hard with some shale streaks.
121.0	125.0	Blue-gray shale.
125.0	134.0	Alternating red, blue, and gray shale.
134.0	142.0	Gypsum.
142.0	147.0	Gray shale.
147.0	164.0	Gray and brown shale with gypsum streaks.
164.0	172.0	Gypsum.
172.0	186.0	Blue shale.
186.0	192.0	Blue and gray shale.

Core Drill

192.0	192.6	Hard silty gypsum.
192.6	194.2	Blue-gray shale with some gypsum in lower part.
194.2	204.0	Brown, blue, and gray gypsiferous shale.
204.0	205.4	Blue-gray gypsiferous shale.
205.4	206.1	Gypsum.
206.1	206.5	Blue shale.
206.5	207.3	Gypsum.
207.3	207.4	Dolomite.

Hole No. E-8 (cont'd)

Core Drill

Depth, feet		Formation
From-	To-	
207.4	210.0	Blue shale with gypsum stringers.
210.0	212.1	Brown, gray, and blue-gray shale.
212.1	213.3	Silty dolomite.
213.3	214.5	Brown and gray silty clay.
214.5	218.0	Red gypsiferous clay.
218.0	220.6	Gypsum interlayered with green shale.
220.6	221.6	Green shale.
221.6	224.0	Brown and green gypsiferous shale.

Analysis, percent

No copper detected.

APPENDIX D.--EQUIPMENT LISTS

Detailed equipment list, mine

1. Dragline (1 required)
   15 cu yd
   Walking dragline with 175-ft boom, transformers and cables
   Drive: electric motor

2. Rotary drill (1 required)
   Rotary drill for blast holes and development drilling
   200 ft depth capacity with tools
   Drive: diesel motor

3. Bulldozer (1 required)
   D-9 Tractor or equivalent, with blade and ripper attachment
   Drive: diesel motor

4. Bulldozer (1 required)
   D-7 Tractor or equivalent, with blade
   Drive: diesel motor

5. Front-end loader (1 required)
   Articulated loader on rubber tires with 4 cu yd dipper
   Drive: diesel motor

6. Pulva-mix cutter (1 required)
   This is a modified asphalt paving cutter with redesigned cutter head
   Drive: diesel motor

7. Trucks (3 required)
   Ten ton dump truck with tandem rear axles
   Drive: diesel motor

8. Service truck
   One and one-half ton flat bed truck with power winch
   Drive: gasoline motor

9. Road patrol (1 required)
   Motorized road grade
   Drive: diesel motor

10. Oil and grease truck (1 required)
    Three-quarter ton pickup truck with greasing equipment to service units
    Drive: gasoline motor

11. Labor shelter (1 required)
    Small building on skids with stove and benches

12. Front-end loader (1 required)
    Front-end loader with 2 cu yd bucket for general service mine-mill and general plant
    Drive: diesel motor

Detailed equipment list, primary crushing

1. Pan feeder (1 required)
   Steel flight conveyor to feed primary crusher
   Variable speed motor
   Drive: 5 hp variable speed motor

2. Jaw crusher (1 required)
   30-in Blake type jaw crusher
   50 hp motor and drive
   Drive: 50 hp W. R. motor

3. Conveyor
   150 ft long 30-in belt with housing above ground surface
   Drive: 30 hp motor

4. Tramp iron magnet
   36-in lifting magnet. 3.5 kw-ac/dc motor generator set
   Drive: 5 hp motor

5. Subsurface hopper
   500 ton capacity/Earth excavation, concrete lined

6. Crusher pit and foundations
   Earth excavations, concrete lined

7. Chutes and gates
   Welded steel construction
   Hopper chute and gate

Detailed equipment list, secondary crushing

1. Hammer mill (1 required)
   Capacity: 150 tph with motor and V-belt drive
   Drive: 150 hp motor

2. Screen (1 required)
   Vibrating screen single deck 4x8 with punched plates
   Drive: 7-1/2 hp motor

3. Return conveyor (1 required)
   50-ft belt conveyor
   18-in belt with housing
   Drive: 10 hp motor

4. Fine ore conveyor (1 required)
   Belt conveyor 120 ft long 30-in belt with housing
   Drive: 30 hp motor

5. Ore sampler (1 required)
   Automatic timed sample cutter to cut ore stream from fine ore conveyor
   Drive: fractional hp motor

6. Ore bin (1 required)
   Circular steel ore bin 30 ft dia 24 ft high with concrete ring foundation

Detailed equipment list, fine grinding

1. Ball mill (2 required)
   6 x 6 cylindrical mills
   169.2 cubic feet capacity
   8.69 tons ball load
   27.2 tph
   Drive: 125 hp motor

2. Classifiers (2 required)
   Screw type - 5x26 ft duplex
   Drive: 5 hp motor

3. Feeder (2 required)
   36-in adjustable stroke feeder
   Capacity: 32 tph
   Drive: 2 hp motor

Detailed equipment list, flotation

1. Conditioner (1 required)
   16x16 steel tank with impeller and motor
   Drive: 20 hp motor

2. Rougher flotation cells (2 units required)
   8 - 42 in x 42 in cells
   Capacity: 630 tons per 24 hours - 7-1/2 hp per cell
   Drive: 8 - 7-1/2 hp motors

3. Cleaner flotation cells (1 unit required)
   4 - 38 in x 38 in cells
   105 to 215 tons per 24 hours - 5 hp per cell
   Drive: 4 - 5 hp motors

4. Lime feeder (1 required)
   Belt delivery dry lime feeder with steel bin and variable speed drive
   Drive: 1/2 hp electric motor and gear reducer

5. Reagent feeder (1 required)
   Disc type wet reagent feeder, four to six discs
   Drive: fractional hp electric motor

6. Spiral thickener (1 required)
   26 ft x 8 ft wood stave tank with spiral rakes and drive mechanism
   17 sq ft settling area per ton
   Drive: 2 hp motor

7. Filter (1 required)
   Disc type. 10 - 6 ft diam discs
   Capacity: 250 lb/sq ft per 24 hours with 22 in x 9 in vacuum pump and accessories
   Drive: vacuum pump motor - 30 hp
   Drive: filter motor - 7-1/2 hp

8. Concentrate dryer (1 required)
   3 ft x 12 ft rotary kiln with butane burner (no refractory lining will be necessary)
   Drive: 5 hp motor and reduction gear

9. Diaphragm pump (2 required)
   6 in simplex
   Drive: 5 hp motor

10. Housing (1 required)
    Prefab metal building
    50 ft x 100 ft x 16 ft. Erected on foundations

Detailed equipment list, tailing disposal and water supply

1. Sand pump (1 required)
   1 - 4 in x 6 in sand pump, 750 gpm, 30 percent solids, 30 ft head
   Drive: 20 hp motor

2. Water supply pump (1 required)
   4 in enclosed impeller pump with suction and valves
   Drive: 10 hp motor
   Capacity: 600 to 700 gpm

APPENDIX E.--COST DATA

TABLE E-1. - Total estimated capital requirements and operating personnel

Item	Cost	Percent	Estimated number operators per day
Acquisition and development ----	$261,600	10.3	--
Mine equipment -----------------	1,200,800	47.2	17
Milling equipment:			
Primary crushing ------------	106,000	4.2	1
Secondary crushing ----------	135,700	5.3	1
Fine grinding ---------------	152,200	6.0	3
Flotation -------------------	179,000	7.0	7
Tailing disposal and water ---	11,100	0.4	1
General plant -----------------	70,400	2.8	7
Subtotal -----------------	2,116,800	83.2	37
Total plant cost insurance and tax base --------------------			$2,116,800
Interest during construction ---	52,900	2.1	
Subtotal for depreciation -	2,169,700	85.3	
Working capital ---------------	373,100	14.7	
Total capital investment --	$2,542,800	100.0	

TABLE E-2. - Mine cost, acquisition and development

Item	Cost
Reconnaissance --------------------	$16,600
Lease acquisition -----------------	7,200
Development -----------------------	194,600
Purchase of plant site ------------	9,200
Water supply pond -----------------	6,200
Tailing disposal pond -------------	20,800
Roads and fences ------------------	7,000
Total -----------------------	$261,600

TABLE E-3. - Mine equipment cost summary

Item	Quantity	Cost		Total cost
		Material	Labor[1/]	
Dragline	1	$900,000	------	
Rotary drill	1	26,000	------	
Bulldozer	1	78,000	------	
Bulldozer	1	32,000	------	
Front-end loader	1	32,300	------	
Pulva-mix cutter	1	30,000	------	
Dump trucks	3	48,000	------	
Service truck	1	6,000	------	
Road patrol	1	20,000	------	
Oil and grease truck	1	4,000	------	
Portable shelter for men	1	1,500	------	
General service loader	1	23,000	------	
Total		$1,200,800	------	$1,200,800

1/ All equipment purchased, delivered, and erected at the mine site.

TABLE E-4. - Milling equipment cost, primary crushing

Item	Quantity	Cost		Total cost
		Material	Labor	
Pan feeder	1	$3,000	$800	
Jaw crusher	1	25,200	6,300	
Belt conveyor	1	11,800	3,000	
Tramp iron magnet	1	2,800	700	
Subsurface hopper	1	2,300	5,100	
Pit and foundations	1	2,400	3,900	
Chutes and gates	1	300	300	
Housing		1,500	1,500	
Electrical		1,000	500	
Total direct		$50,300	$22,100	$72,400
Field indirect				11,000
Total construction				83,400
Engineering				4,200
Overhead and administration				4,200
				91,800
Contingency				9,200
				101,000
Fee				5,000
				$106,000

TABLE E-5. - Milling equipment, secondary crusher

Item	Quantity	Cost		Total cost
		Material	Labor	
Hammer mill ------------------	1	$33,500	$8,400	
Screen -----------------------	1	3,000	700	
Return conveyor --------------	1	5,800	1,500	
Fine ore conveyor ------------	1	13,100	3,300	
Ore sampler ------------------	1	1,500	400	
Ore bin ----------------------	1	21,600	-----	
Housing ----------------------		2,000	2,000	
Electrical -------------------		1,000	500	
Total direct ------------		$81,500	$16,800	$98,300
Field indirect ---------------				8,400
Total construction -----------				106,700
Engineering ------------------				5,400
Overhead and administration --				5,400
				117,500
Contingency ------------------				11,700
				129,200
Fee --------------------------				6,500
Total-------------------				$135,700

TABLE E-6. - Milling equipment costs, fine grinding

Item	Quantity	Cost		Total cost
		Material	Labor	
Ball mills --------------	2	$66,600	$13,200	
Classifiers -------------	2	16,000	3,200	
Feeders -----------------	2	6,000	1,200	
Housing -----------------		Included in	flotation	
Foundations -------------		700	1,400	
Electrical --------------		1,000	500	
Total direct -------		$90,300	$19,500	$109,800
Field indirect ----------				10,000
Total construction -				119,800
Engineering -------------				6,000
Overhead and administration --------				6,000
				131,800
Contingency -------------				13,200
				145,000
Fee ---------------------				7,200
				$152,200

TABLE E-7. - Milling equipment costs, flotation

Item	Quantity	Cost		Total cost
		Material	Labor	
Conditioner -------------	1	$2,900	$700	
Rougher flotation units -	2	24,800	6,200	
Cleaner flotation unit --	1	4,900	1,200	
Lime feeder -------------	1	900	200	
Reagent feeder ----------	1	800	200	
Spiral thickener --------	1	5,300	1,300	
Filter ------------------	1	21,900	5,500	
Dryer -------------------	1	3,600	900	
Diaphragm pump ----------	2	4,200	1,100	
Prefab building ---------	1	33,600	-----	
Foundations -------------		1,700	2,000	
Electrical --------------		2,000	1,000	
Piping ------------------		1,500	800	
Heating -----------------		800	300	
Total cost ---------		$108,900	$21,400	$130,300
Field indirect ----------				10,700
Total construction -				141,000
Engineering -------------				7,000
Supervision and administrative --------				7,000
				155,000
Contingency -------------				15,500
				170,500
Fee ---------------------				8,500
				$179,000

TABLE E-8. - Milling equipment costs, tailing disposal and water supply

Item	Quantity	Cost		Total cost
		Material	Labor	
Sand pump ----------------		$2,200	$600	
Discharge pipe -----------		1,900	500	
Water supply pump --------		900	200	
Discharge pipe -----------		900	200	
Electrical ---------------		400	200	
Total direct --------		$6,300	$1,700	$8,000
Field indirect -----------				800
Total construction --				8,800
Engineering --------------				400
Overhead and administration ---------				400
				9,600
Contingency --------------				1,000
				10,600
Fee ----------------------				500
				$11,100

TABLE E-9. - General plant costs

Item	Quantity	Cost		Total cost
		Material	Labor	
Office and laboratory ---		$6,900	-----	
Heaters -----------------		300	$100	
Office equipment --------		4,500	-----	
Laboratory equipment ----		6,000	-----	
Sample shed -------------		1,200	-----	
Water supply and sewage disposal --------------		3,000	-----	
Secondary transformers --	3	5,000	-----	
Shop building -----------		16,000	-----	
Shop equipment ----------		4,000	-----	
Truck scales ------------		3,000	1,500	
Fuel tanks --------------		300	100	
Electrical --------------		1,500	700	
Total direct -------		$51,700	$2,400	$54,100
Field indirect ----------				1,200
				55,300
Engineering -------------				2,800
Overhead and administration --------				2,800
				60,900
Contingency -------------				6,100
				67,000
Fee ---------------------				3,400
				$70,400

TABLE E-10. - Estimated annual product cost income

Direct cost		
Utilities		
Electric power		
Mine -----------4,670,000 kw @10 mills --	$46,700	
Mill -----------2,140,000 kw @10 mills --	21,400	
		$68,100
Direct labor		
Mine -----------------------------------	256,700	
Mill -----------------------------------	120,000	
		376,700
Repairs and supplies		
Mine -----------------------------------	168,800	
Mill -----------------------------------	88,900	
		257,700
Payroll overhead 25% --		94,200
Total direct cost ---		796,700
Indirect cost (administration and overhead) ---------------------		291,400
Fixed cost		
Taxes and insurance--2% of plant --------------------------		42,300
Allowance for depreciation		
(10 years) Mine 10% -------------------------	$146,300	
(14 years) Mill 7.1% ------------------------	46,500	
(14 years) Interest 7.1% --------------------	3,800	
		196,600
Total gross production cost ------------------------------		1,327,000
Annual concentrate sales --		1,597,000
Less production costs ---		1,327,000
Income before taxes --		270,000
Depletion computations		
(a) 15% of sales (15% x $1,597,000 = $239,600)		
(b) 50% of income before taxes and depletion (50% x $270,000 = $135,000)		
Income before taxes ---		270,000
Allowance for depletion ---		135,000
Taxable income ---		135,000
Federal income tax 50% --		67,500
Net income ---		$67,500

TABLE E-11. - Estimated working capital

Item	Days	Amount capital	Percent
Payroll --------------	65	$94,200	25
Repairs and supplies -	65	94,100	25
Concentrate production	30	184,800	50
Total -----------		$373,100	100

TABLE E-12. - Discounted cash flow for plant investment

Year	Income after taxes	Depreciation		Depletion	Cash flow	Present value factor for 12 percent	Present value
		Mine	Mill				
1 --	$67,500	$146,300	$50,300	$135,000	$399,100	0.893	$356,400
2 --	67,500	146,300	50,300	135,000	399,100	0.797	318,100
3 --	67,500	146,300	50,300	135,000	399,100	0.712	284,200
4 --	67,500	146,300	50,300	135,000	399,100	0.636	253,800
5 --	67,500	146,300	50,300	135,000	399,100	0.567	226,300
6 --	67,500	146,300	50,300	135,000	399,100	0.507	202,300
7 --	67,500	146,300	50,300	135,000	399,100	0.452	180,400
8 --	67,500	146,300	50,300	135,000	399,100	0.404	161,200
9 --	67,500	146,300	50,300	135,000	399,100	0.361	144,100
10 --	67,500	146,300	50,300	135,000	399,100	0.322	128,500
11 --	80,000	-------	50,300	160,200	290,500	0.287	83,400
12 --	80,000	-------	50,300	160,200	290,500	0.257	74,700
13 --	80,000	-------	50,300	160,200	290,500	0.229	66,500
14 --	80,000	-------	50,300	160,200	290,500	0.205	59,600
Total	$995,000	$1,463,000	$704,200	$1,990,800	$5,153,000	-----	$2,539,500

Net Annual Receipts

Net annual income of $1,597,000 would be needed to maintain a 12-percent discount cash flow.

Net value of a 40-percent-copper concentrate based on 42.114 cent per pound copper (average August 1968) and existing freight and smelting charges--$264.28 per ton.

$$\frac{\$1,597,000}{264.28} = 6,043 \text{ tons of concentrates needed annually}$$

$$\frac{6,043}{260} = 23.2 \text{ tons of concentrates per day}$$

$$23.2 \times 40\% = 9.28 \text{ tons copper in concentrate}$$

$$\frac{9.28 \text{ tons of copper in concentrate}}{1,000 \text{ tons ore milled per day}} = 0.928 \text{ percent copper recovered from mine ore}$$